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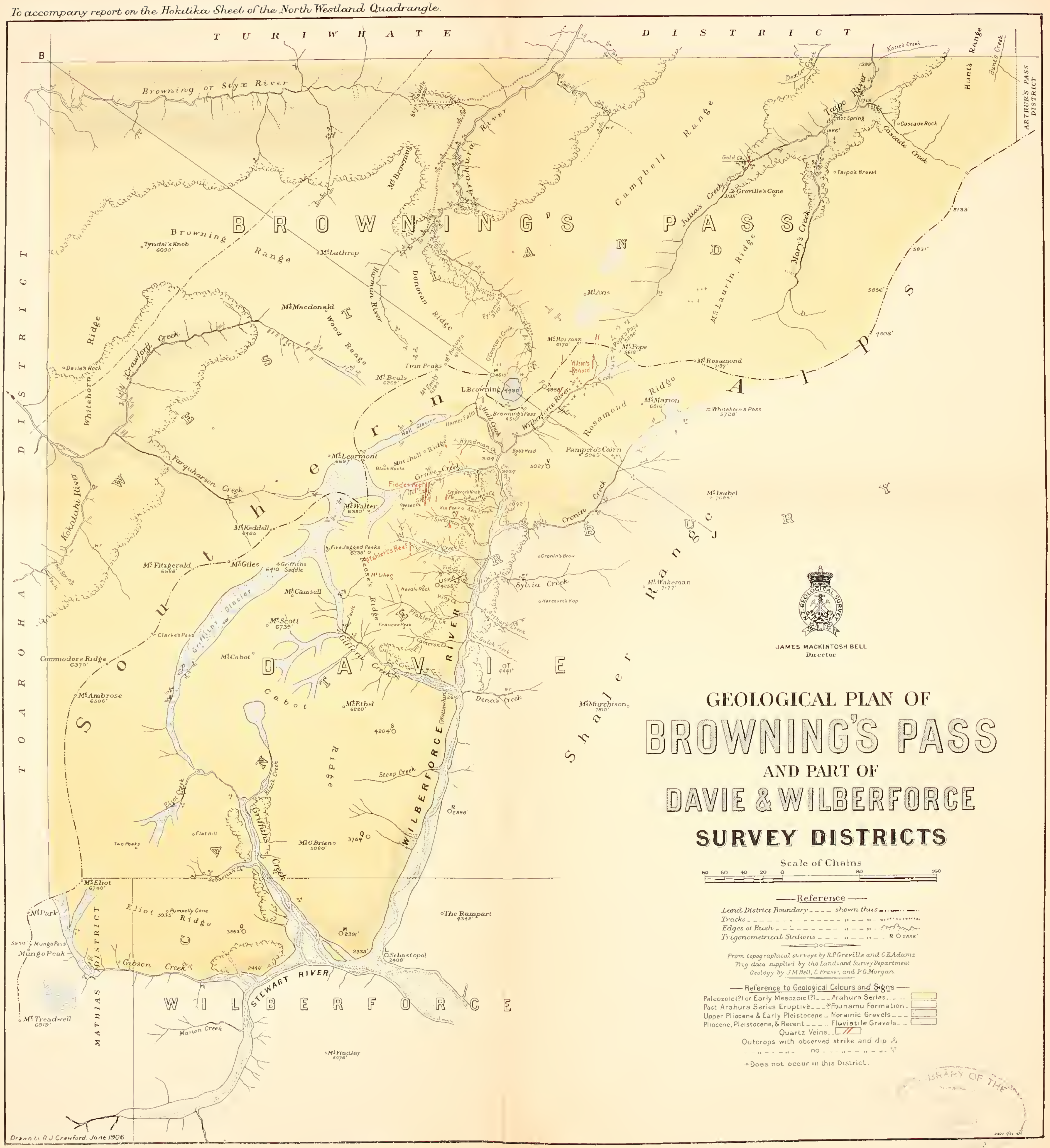
*To accompany report on the Hokitika Sheet of the North Westland Quadrangle.*



# GEOLOGICAL PLAN OF
# BROWNING'S PASS
## AND PART OF
# DAVIE & WILBERFORCE
# SURVEY DISTRICTS

Scale of Chains

80 60 40 20 0 80 160

—— Reference ——

*Land District Boundary* - - - - *shown thus*
*Tracks* - - - - - - - - - - " - - "
*Edges of Bush* - - - - - - - - " - - "
*Trigonometrical Stations* - - - " - - " - - R ○ 2888'

*From topographical surveys by R.P. Greville and C.E. Adams*
*Trig data supplied by the Land and Survey Department*
*Geology by J.M. Bell, C. Fraser, and P.G. Morgan.*

—— Reference to Geological Colours and Signs ——

| | | |
|---|---|---|
| Paleozoic(?) or Early Mesozoic(?) | Arahura Series | ▭ |
| Post Arahura Series Eruptive | *Pounamu Formation | ▭ |
| Upper Pliocene & Early Pleistocene | Morainic Gravels | ▭ |
| Pliocene, Pleistocene, & Recent | Fluviatile Gravels | ▭ |

Quartz Veins - - //

Outcrops with observed strike and dip
- - " - - - " - no - - " - - " - " -

*Does not occur in this District.

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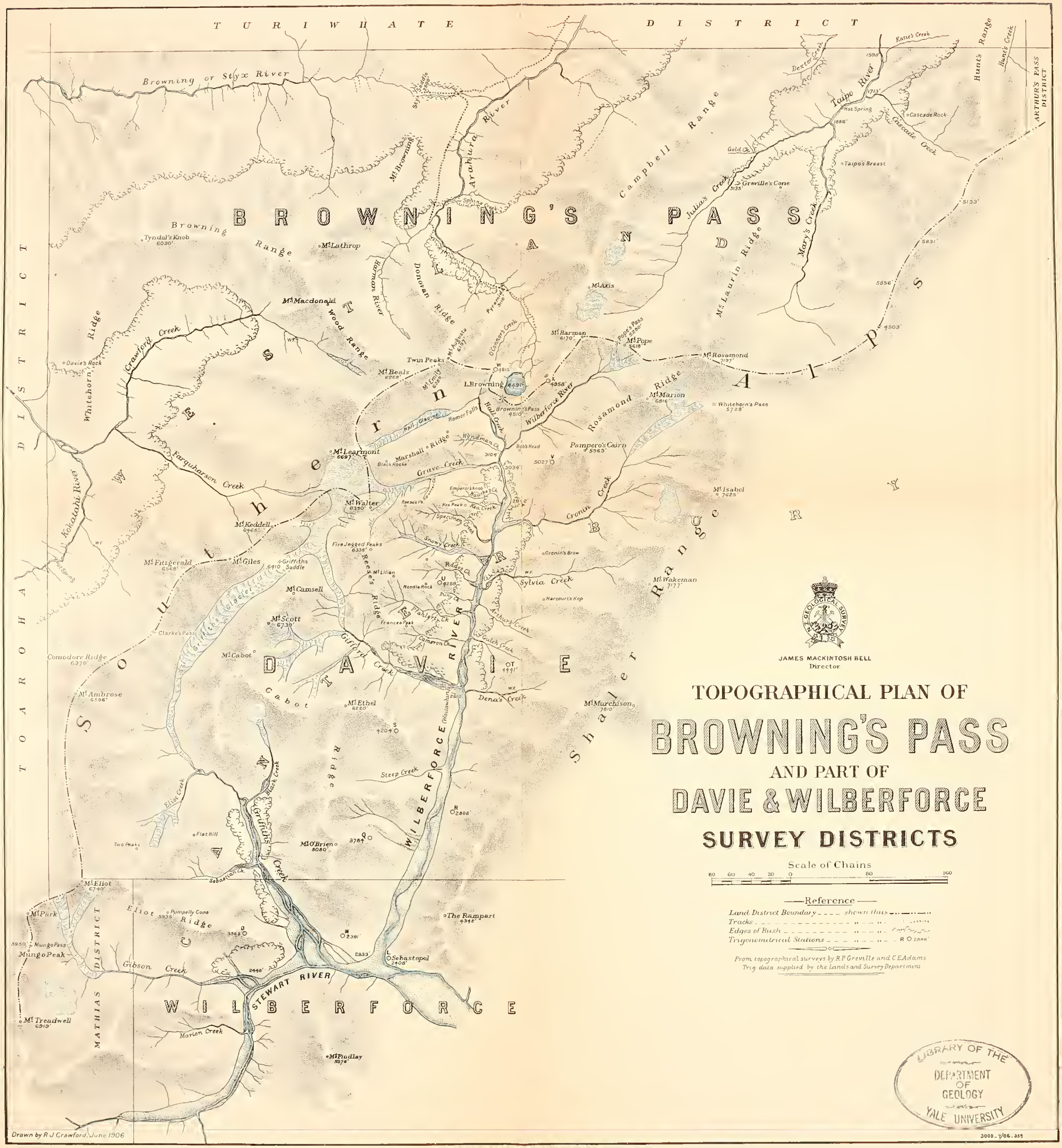

JAMES MACKINTOSH BELL
Director

# TOPOGRAPHICAL PLAN OF
# BROWNING'S PASS
# AND PART OF
# DAVIE & WILBERFORCE
# SURVEY DISTRICTS

Scale of Chains
80 60 40 20 0 80 160

Reference

*Land District Boundary* ---- shown thus -·-·-
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*Trig data supplied by the Lands and Survey Department*

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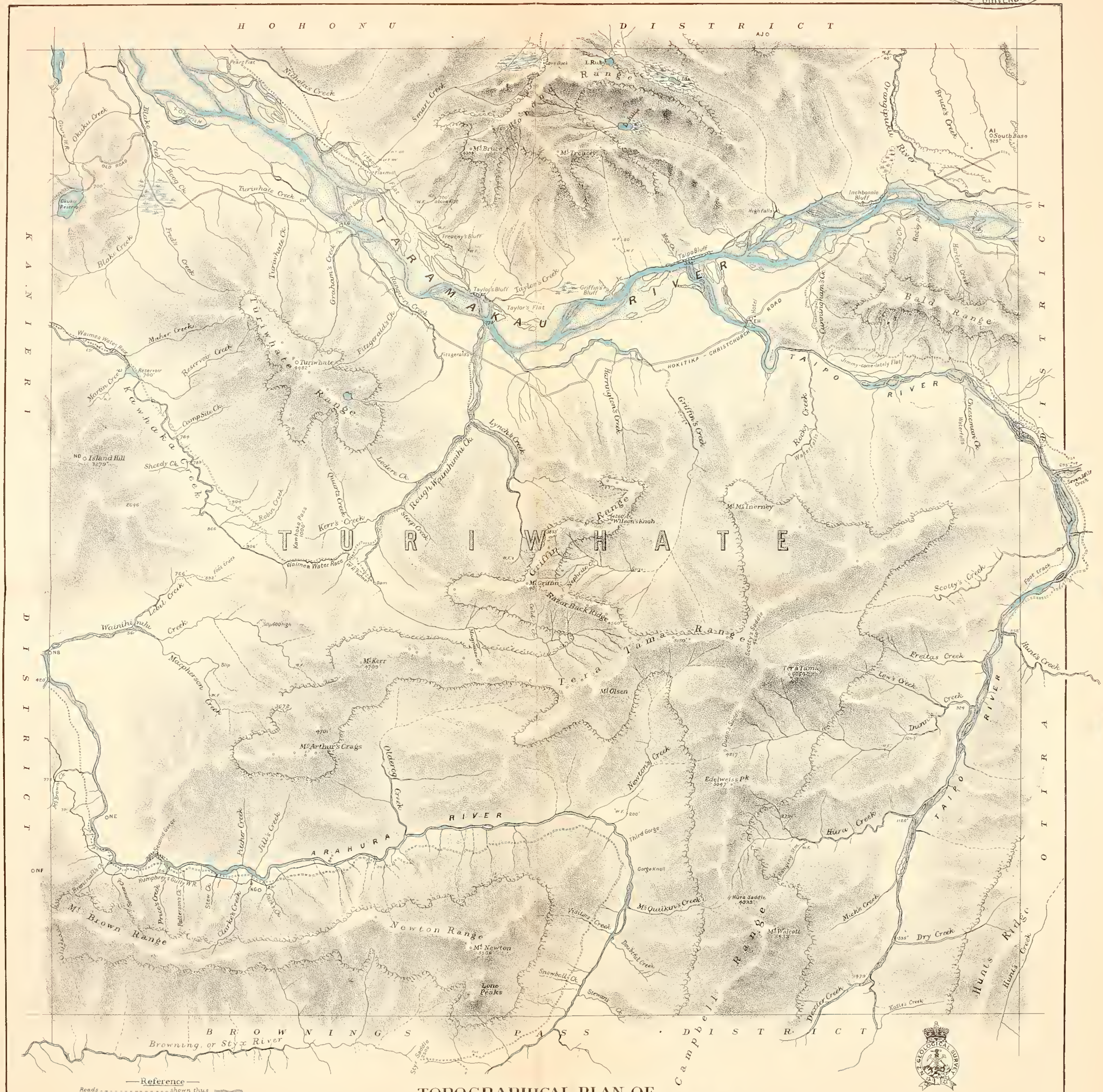

—Reference—

| | |
|---|---|
| Roads | shown thus |
| Tracks | " |
| Tram Lines | " |
| Water Races | " |
| Edges of Bush | " |
| Swamp | " |
| Trigonometrical Stations | " ONE |
| Mountain Peaks | " |

# TOPOGRAPHICAL PLAN OF
# TURIWHATE SURVEY DISTRICT

Scale of Chains

80 60 40 20 0 80 160

JAMES MACKINTOSH BELL
Director

Compiled from data obtained from the Lands and Survey Department, and surveys executed by J.M.Bell, R.P.Greville, P.G.Morgan, and C.Fraser, of the Geological Survey Branch of the Mines Department, and their assistants.

Compiled and drawn by R.J.Crawford May 1906

To accompany report on the Hokitika Sheet of North Western Quadrangle.

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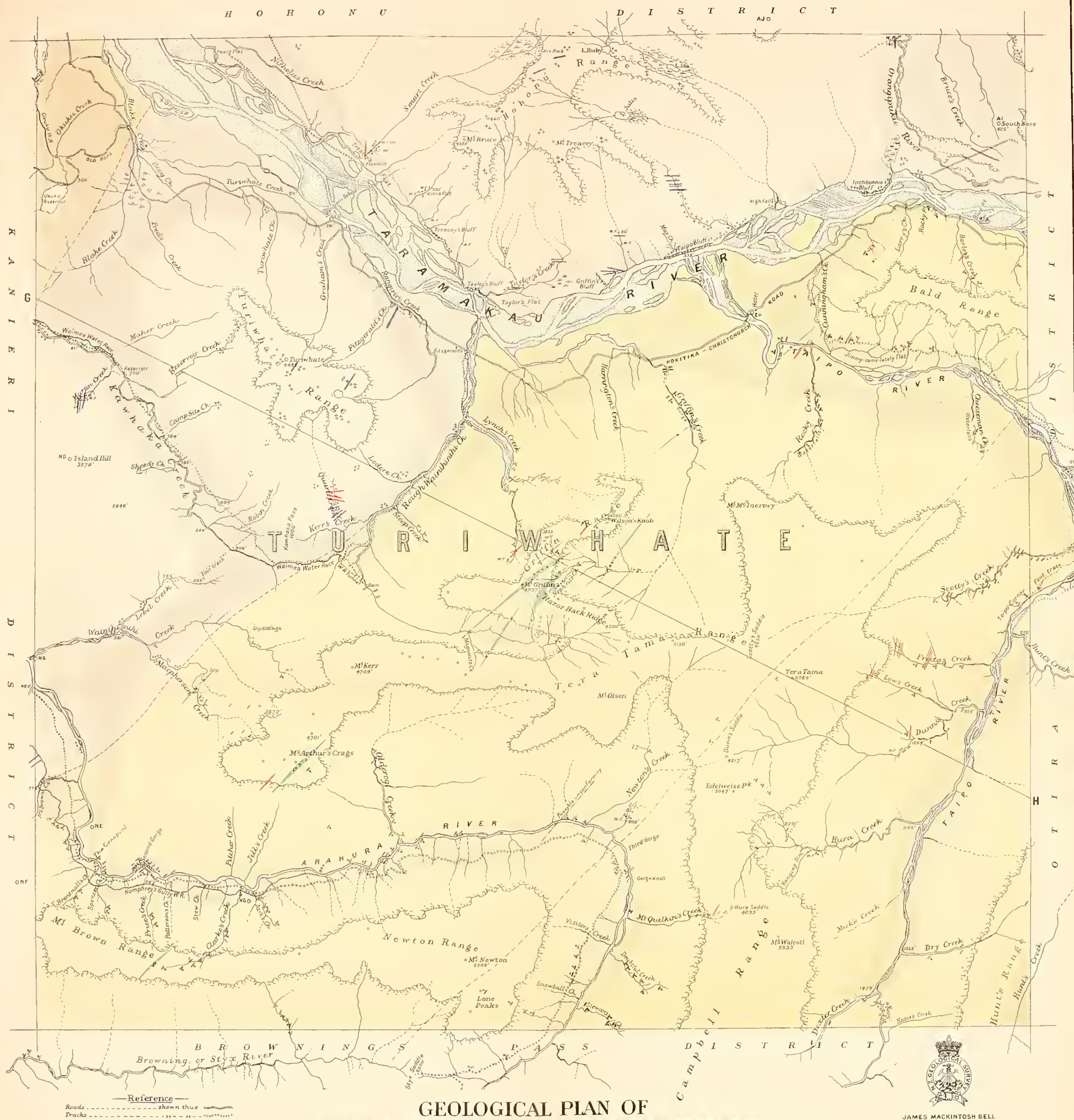

## GEOLOGICAL PLAN OF

## TURIWHATE SURVEY DISTRICT

Scale of Chains

80 60 40 20 0 80 160

**Reference**

Roads ............ shown thus

Tracks ............ " ............

Tram Lines ............ " ............

Water Races ............ " ............

Edges of Bush ............ " ............

Swamp ............ " ............

Trigonometrical Stations ............ " ............ ONE

Mountain Peaks ............ " ............ ○

**Reference to Geological Colours and Signs**

Paleozoic(?) or Early Mesozoic (?)
- Arahura Series ☐
- * Kanieri Series ☐

Post Arahura Series Eruptives
- Pounamu Formation ▨
- Tuhua Granites &c. ☐
- Basic Dykes ▨

Late Cretaceous or Early Tertiary
- * Koiterangi Series ☐

Miocene
- Blue Bottom ☐

Early Pliocene
- * Humphrey's Gully Beds ☐

Upper Pliocene & Early Pleistocene
- Morainic Gravels ☐

Pliocene, Pleistocene & Recent
- * Marine Gravels ☐
- Fluviatile Gravels ☐
- Quartz Veins ▨

Outcrops with observed strike and dip

Outcrops with no strike and dip

Outcrops with horizontal strata

* Does not occur in this District.

JAMES MACKINTOSH BELL
Director

*Compiled from data obtained from the Lands and Survey Department, and surveys executed by J.M.Bell, R.P.Greville, P.G.Morgan, and C.Fraser, of the Geological Survey Branch of the Mines Department, and their assistants*

*Compiled and drawn by R.J.Crawford, May 1906*

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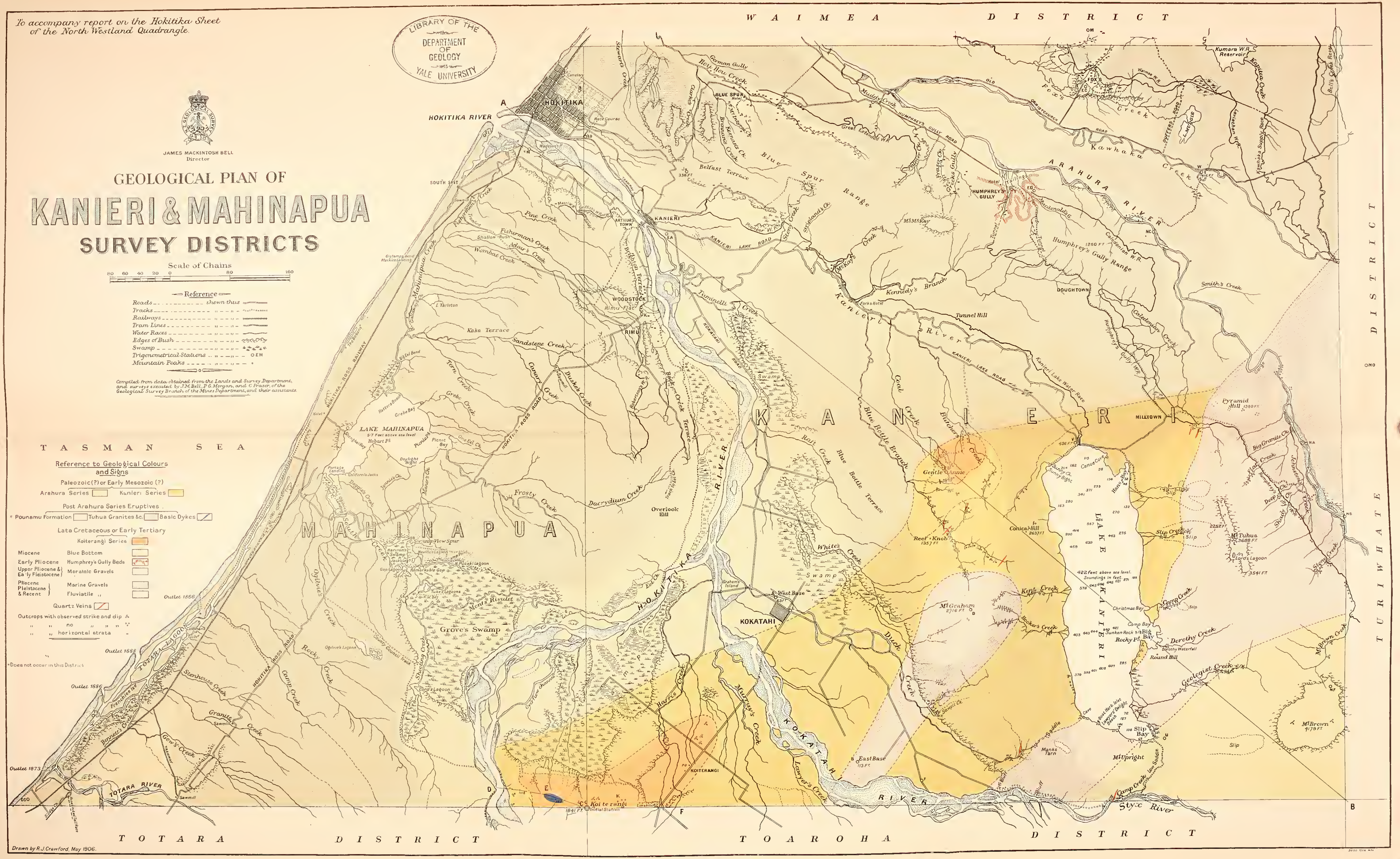
Director

# GEOLOGICAL PLAN OF
# KANIERI & MAHINAPUA
# SURVEY DISTRICTS

Scale of Chains



Reference

Roads ………… shown thus
Tracks ………… " — " —
Railways ………… " — " —
Tram Lines ………… " — " —
Water Races ………… " — " —
Edges of Bush ………… " — " —
Swamp ………… " — " —
Trigonometrical Stations ………… " — " — O E M
Mountain Peaks ………… " — " — •

*Compiled from data obtained from the Lands and Survey Department, and surveys executed by J.M. Bell, P.G. Morgan, and C Fraser, of the Geological Survey Branch of the Mines Department, and their assistants.*

Reference to Geological Colours and Signs

Paleozoic(?) or Early Mesozoic (?)
Arahura Series ☐ Kanieri Series 🟨

Post Arahura Series Eruptives
* Pounamu Formation ☐ Tuhua Granites &c. ☐ Basic Dykes ▨

Late Cretaceous or Early Tertiary
Koiterangi Series 🟧

Miocene — Blue Bottom ☐
Early Pliocene — Humphrey's Gully Beds ▨
Upper Pliocene & Early Pleistocene — Morainic Gravels ☐
Pliocene Pleistocene & Recent — Marine Gravels ☐
Fluviatile " ☐

Quartz Veins ▨

Outcrops with observed strike and dip
" " no " " "
" " horizontal strata

*Does not occur in this District

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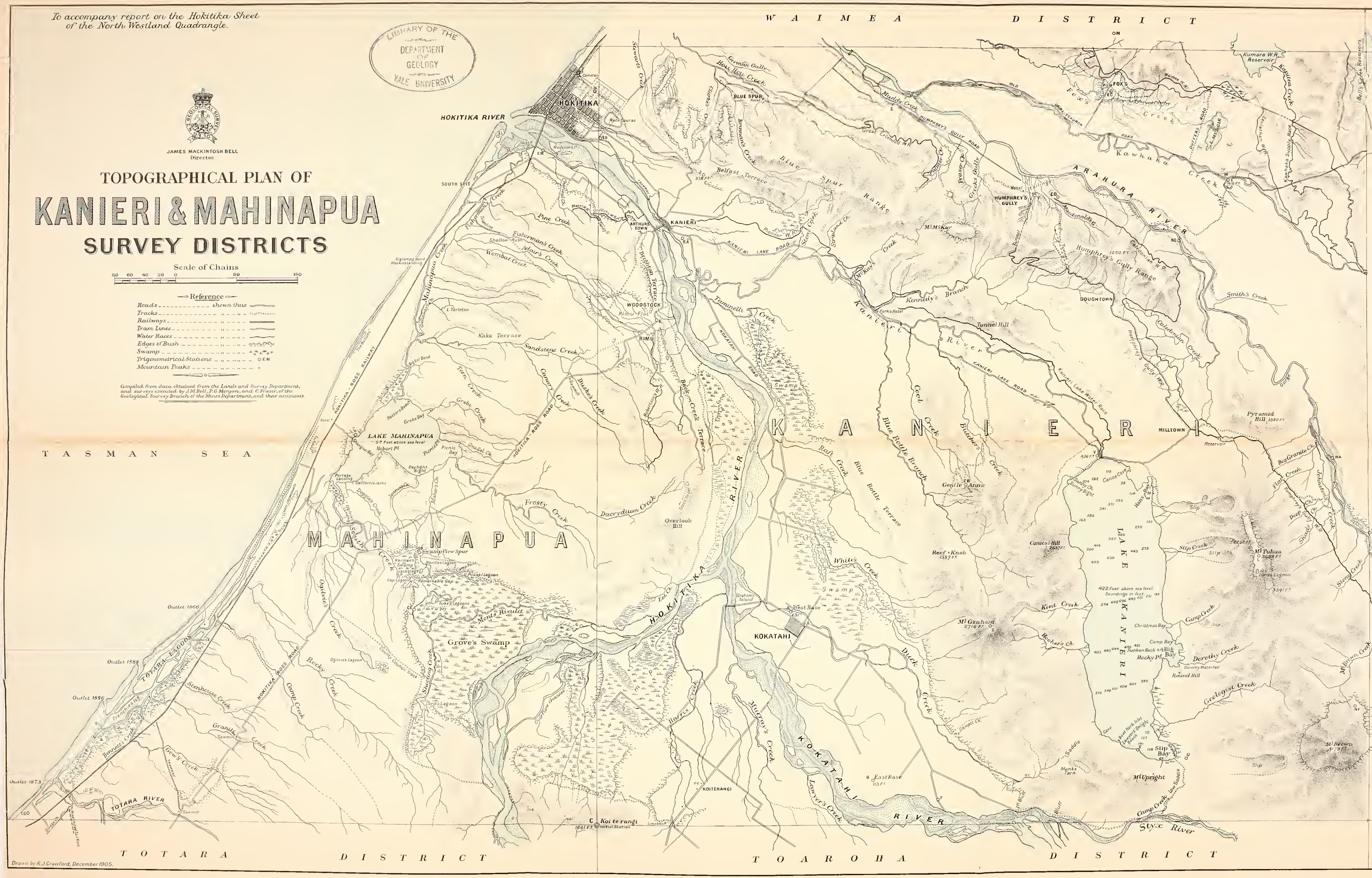
# TOPOGRAPHICAL PLAN OF
# KANIERI & MAHINAPUA
# SURVEY DISTRICTS



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Drawn by R. J. Crawford, December 1905.

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LAKE KANIERI.

*Geological Bulletin.*] [*Frontispiece.*

Map
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Department of Mines.

NEW ZEALAND GEOLOGICAL SURVEY.

BULLETIN No. 1 (NEW SERIES).

# THE GEOLOGY OF THE HOKITIKA SHEET, NORTH WESTLAND QUADRANGLE,

## WITH WHICH HAS BEEN INCLUDED A SMALL PORTION OF THE UPPER WILBERFORCE VALLEY, IN THE WAIMAKARIRI QUADRANGLE.

BY

JAMES MACKINTOSH BELL, M.A., PH.D., F.R.G.S.,

ASSISTED BY

COLIN FRASER, M.Sc.

ISSUED UNDER THE AUTHORITY OF THE HON. JAMES McGOWAN, MINISTER OF MINES.

NEW ZEALAND.
BY AUTHORITY: JOHN MACKAY, GOVERNMENT PRINTER, WELLINGTON.

1906.

# LETTER OF TRANSMITTAL.

Department of Mines,
New Zealand Geological Survey,
Wellington, 1st June, 1906.

Sir,—

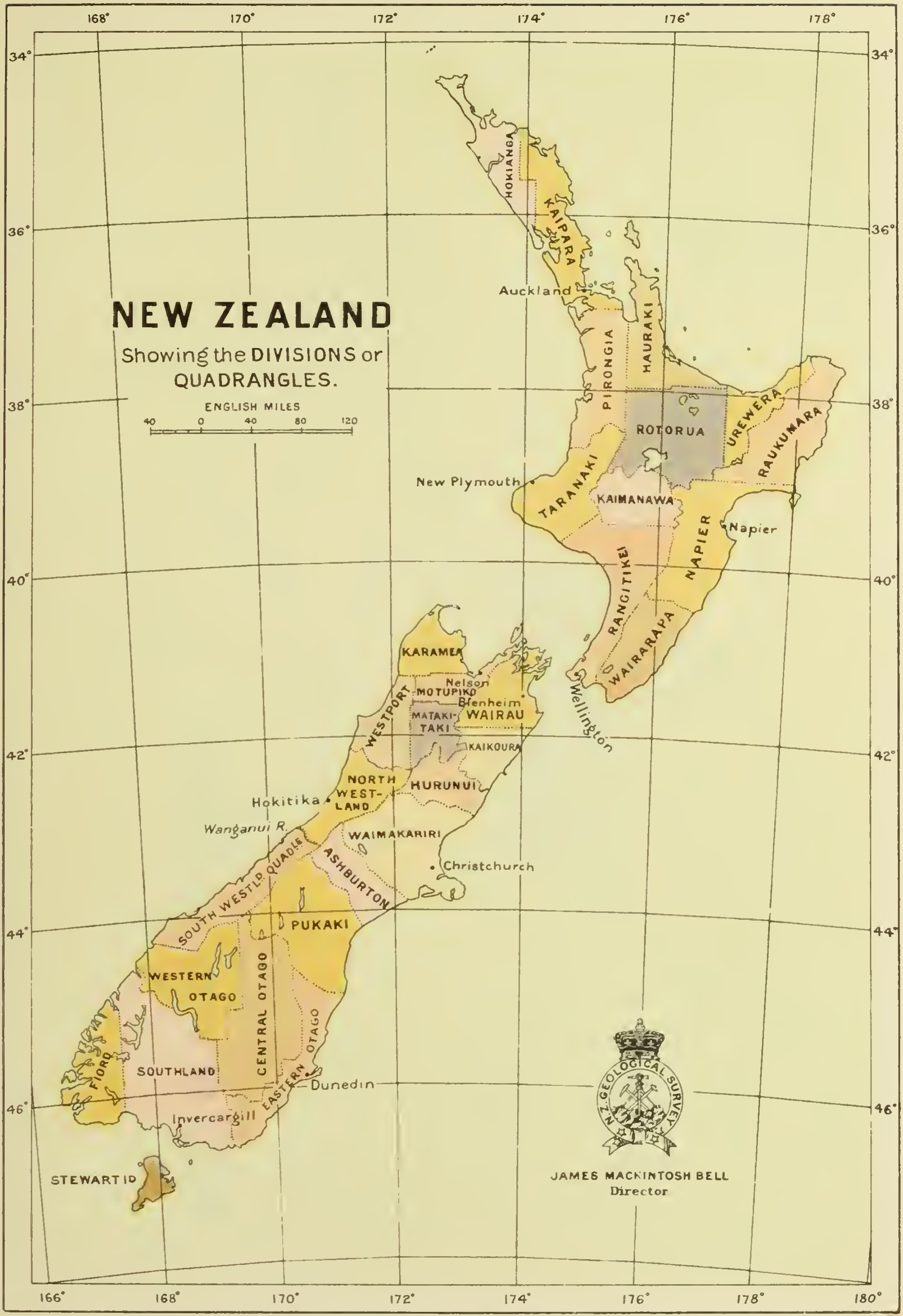
I have the honour to submit herewith Bulletin No. 1 (new series) of the New Zealand Geological Survey.

The volume comprises 101 pages. It is accompanied by thirteen maps and sectional plans, and is illustrated by forty-two plates.

I have the honour to be,
Sir,
Your obedient servant,
JAMES MACKINTOSH BELL,
Director.

Hon. James McGowan,
Minister of Mines, Wellington.

*To accompany report on the Hokitika Sheet of the North Westland Quadrangle.*



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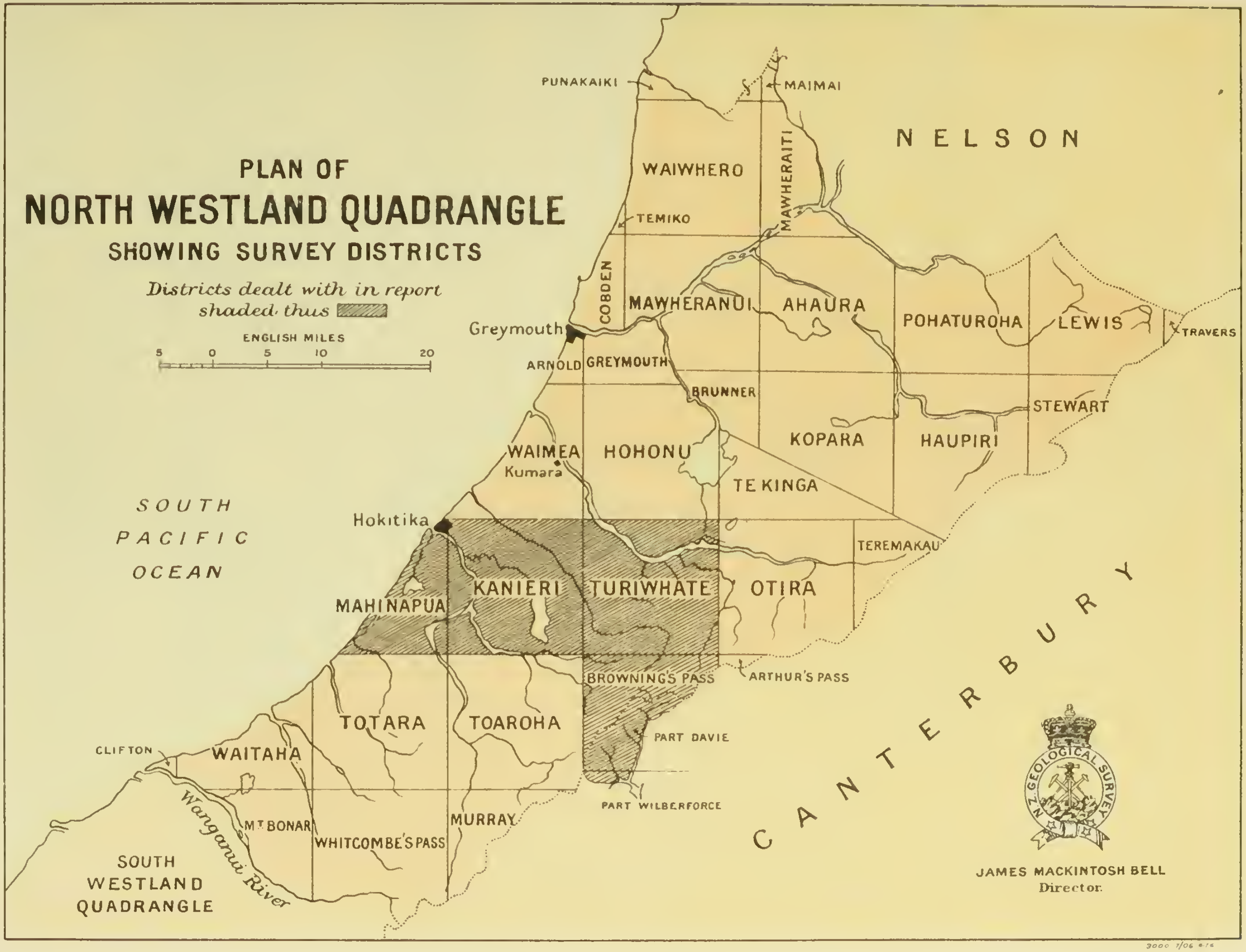

PLAN OF
NORTH WESTLAND QUADRANGLE
SHOWING SURVEY DISTRICTS

*Districts dealt with in report shaded thus* ▨

JAMES MACKINTOSH BELL
Director.

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# PREFACE.

THE work on the Hokitika Sheet of the North Westland Quadrangle has been completed after some thirteen months' labour spent almost continuously in the field. The survey has been conducted under my direct supervision, with Mr. Colin Fraser as chief geological assistant and Mr. R. P. Greville as chief topographical assistant. In the geological field-work Mr. Fraser and myself received much valuable help from Mr. P. G. Morgan, who has been engaged in the field-work in the next sheet south of the Hokitika Sheet—the Mikonui Sheet. Mr. C. E. Adams, formerly on the staff of the Geological Survey, did a little mapping prior to Mr. Greville's arrival.

In the preparation of the accompanying geological report on the Hokitika Sheet Mr. Fraser and I have co-operated. We have received much kindly help from Mr. Alexander McKay, whose intimate knowledge of the Westland District has been of great value to us. The maps and cross-sections illustrating the report have in part been prepared from original work of the Geological Survey staff, and in part compiled from valuable data kindly given by the Lands and Survey Department. This section of the work has fallen to Mr. R. J. Crawford, Chief Draughtsman, and to Mr. Greville.

It gives me pleasure here to formally express my grateful appreciation of the services rendered us by Dr. J. S. Maclaurin, Colonial Analyst, and his assistant, Mr. William Donovan, by whom all the analyses in this report, excepting where specifically mentioned to the contrary, were made. I am also anxious to acknowledge my indebtedness to many people in Westland for much help received during the carrying-on of the field labour. It is impossible here to especially mention all who helped us in this way, but I desire to make special mention of the kindly assistance given by Mr. G. J. Roberts, Commissioner of Crown Lands for Westland.

JAMES MACKINTOSH BELL,
Director of the Geological Survey.

### BULLETIN No. 1 (NEW SERIES).

# GEOLOGY OF HOKITIKA SHEET,

## NORTH WESTLAND QUADRANGLE.

## CHAPTER I.

## GENERAL AND HISTORICAL INFORMATION.

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History of gold-mining on the West Coast .. .. 2
Methods of winning gold.. .. .. .. 3
Area described in this Bulletin .. .. .. 5
Plan of conducting work.. .. .. .. 5
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### INTRODUCTION.

PERHAPS no part of the world is more interesting geologically than the Islands of New Zealand, and no section of the country is more remarkable than the western watershed of the Alps of the South Island, which includes the District of Westland. The district stretches from the Island divide to the shores of the Tasman Sea, and is bounded on the south by a line drawn from Big Bay to Mount Aspiring, and in the north by the Pororari River, the Otutu River, the Grey River, and an irregular line ending at the Alps near Lake Christabel. The district exhibits phenomena which exemplify almost every phase of geological interest. The rugged chain of the Alps presents structural features on a grand scale. The splendid glaciers which descend from them rival the ice rivers of the Swiss Alps and of the Caucasus, while in almost every river in the area are located hot springs, one at least of which is depositing sinter terraces of some size. The broken lands towards the north of the district supply a large proportion of the coal-supply of New Zealand,* while the sandy shore, the river beaches, and the various terraces of the narrow coastal plain of Westland have given sufficient alluvial gold to rank the district among the leading placer fields of the globe.

### ECONOMIC REASONS FOR THE WORK IN WESTLAND.

Not only, then, from purely scientific reasons, but more particularly from economic reasons, a detailed survey of Westland seemed most necessary. There were many problems relating to this utilitarian side, which it was hoped a careful survey might at least partially elucidate. Some of these may be enumerated.

(1.) Despite the wide extent and great wealth of the alluvial fields of Westland, very few auriferous quartz veins, from which it might reasonably be expected this large supply of the precious metal has originated, had been discovered, and it was thought that in the wild, rugged, and practically unexplored hinterland might perhaps be found some of the mother veins of this detrital wealth.

---

* During the year 1905 Westland supplied 275,752 tons out of a total of 1,585,756 tons of coal produced in New Zealand.

(2.) Again, the surface alluvial workings, which have given such great wealth in the past, have recently rapidly diminished in yearly output, and this exhaustion or partial exhaustion of many of the diggings has rendered the discovery of new mining areas very desirable. It was considered possible that a searching investigation might bring new fields to light, or at least answer the much debated question negatively.

(3.) Furthermore, since no really deep alluvial ground (deep leads) had been discovered north of Ross, it was necessary to endeavour to definitely ascertain the existence or non-existence of these leads in the formerly more richly auriferous northern portion of the district.

Of these three problems, the first mentioned—that is, a critical exploration for auriferous quartz veins—seemed much the most salient and most likely to be productive of important results, since deposits of this nature were already known to exist near Browning's Pass, on the lower waters of the Taipo River, and elsewhere.

(4.) Another question that seemed to warrant distinct inquiry was an investigation of the Westland coalfields, in order to determine whether any large extension of their boundaries might be contemplated. Still further, it was hoped that discoveries of metalliferous deposits, other than auriferous lodes, might be made in the *terra incognita* in the eastern part of the district.

Of course, a search for the economic minerals such as has just been outlined required a study, not only of the economic geology of the area, but of every phase of that subject; although, as much the most important in any new country, the economic side was that kept chiefly in evidence.

Even apart from the pure geological investigations, an examination of the lakes and rivers, in order to ascertain how far they were available for supplying water-power to be used more particularly for hydraulic mining, was urgently required; and, finally, general information as to the natural resources of the district—for example, its wealth in timber and the potentialities of its soil for agriculture—seemed to be needed, and in various parts of this report references are made to these points, as well as to many others which have arisen since the work was started.

## HISTORY OF GOLD-MINING ON THE WEST COAST.

Like all the world's gold rushes, the history of gold-mining on the West Coast reads like a romance. The precious metal is said to have been first discovered by Mr. John Rochfort during an exploring expedition made from Nelson to the West Coast many years before the great rush of 1865.* It was not until the end of 1864, however, that the discovery of rich "wash-dirt" in the Greenstone district, and later on near the Hokitika River, called public attention to the golden possibilities of Westland, and soon men from all parts of Australasia were rushing towards the new Eldorado. In March, 1865, a great influx of hardy miners from Otago, Victoria, and elsewhere set in. Means of communication were difficult in those early days. The West Coast possesses few harbours save those which exist behind wide sand-bars, which are traversable with great difficulty except on favourable occasions, and the whole shore exposed to the full sweep of the prevailing westerly winds is one of broken and tempestuous seas. Most of the earlier diggers reached the goldfield in open boats, coming up the coast from Dunedin or the Bluff. The record of these adventurous cruises is one of thrilling interest. Some started on their voyage never to be heard of again, while others only reached their goal after enormous hardships. Others of the first miners to arrive in the field, after following the wild Canterbury rivers to their headquarters, crossed unexplored alpine passes, and made their way as best they could through the dense trackless forest of Westland or along the rapid, boulder-strewn rivers to the coast. The story of the vicissitudes and hardships endured by these early pioneers forms a splendid monument in the early history of New Zealand.

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* See "The Gold Coast," R. C. Reid, p. 20.

Notwithstanding the lack of roads and the thick bush the diggers soon made their way into the most remote parts of the district, and, though the hardships were great, the rewards were often of corresponding proportions. In most localities the gold was near the surface, and easily obtained. Along the sea-beaches it is said the surface of the sand was not seldom yellow with gold. At the Kanieri, three miles from the mouth of the Hokitika River, 1 dwt. to 2 dwt. of gold to the dish was commonly obtained, and at Woodstock, across the Hokitika River, the diggers are said to have made £15 a week per man, and at Tucker Flat, near the Kanieri, the weekly earnings were £6 to £30 per man. The richest ground seems to have been the Auckland Beach, a few miles north of Hokitika, where 1 dwt. to 7 oz. of gold to the dish was obtained, and individual miners panned or cradled 25 oz. and even 100 oz. of gold week after week. The Okarito Beach, some fifty-five miles south-west of Hokitika, was another very rich locality.

At the very beginning of the goldfields a village of tents sprang up on the sea-beach near the mouth of the Hokitika River, and soon this grew into a mushroom mining town. The river was crowded with shipping of all sizes up to 200 or 300 tons, and larger vessels unable to cross the shallow bar might have been seen lying in the open roadstead. It is said that after a spell of bad weather had rendered the bar impassable for a few days, as many as a hundred vessels might have been seen in the offing awaiting an opportunity to enter the harbour.

In the early days there were no roads other than the sea-beach, the shingly river-beds, and the rough tracks made by the miners themselves. The dense bush made locomotion very difficult, the heavy rainfall often causing the unmetalled tracks to become almost impassable.

Within two years of the first rush the maximum output of gold was obtained. Since then the production has steadily declined, though now and then fresh discoveries have given a temporary impetus to the industry. Up to the close of 1905 the total output had reached the enormous amount of 5,132,929 oz., of the value of £20,432,079. The most notable finds since the early days have been at Kumara (1875), Back Creek, near Rimu (1882), Craig's Freehold, near Hokitika, and Arahura Flat. That these last three named localities, so very close to the earliest centre of the goldfield, should have remained so long undiscovered seems remarkable, and points to the possibility of rich deposits still existing in places supposed to be thoroughly prospected.

Very little reef-mining has been done in Westland, and what has been undertaken has not been successful. In 1889 several small quartz veins were exploited on Kelly's Range, near Jackson's station, and somewhat more recently a small battery was erected in the same locality by the Teremakau Gold Company. The property is said to have failed not so much from absence of auriferous quartz as owing to mismanagement. A similar fate seems to have befallen reefing operations which were undertaken on Cedar Creek, near Ross. Some prospecting was done on Mount Rangitoto, at Gentle Annie, and elsewhere.

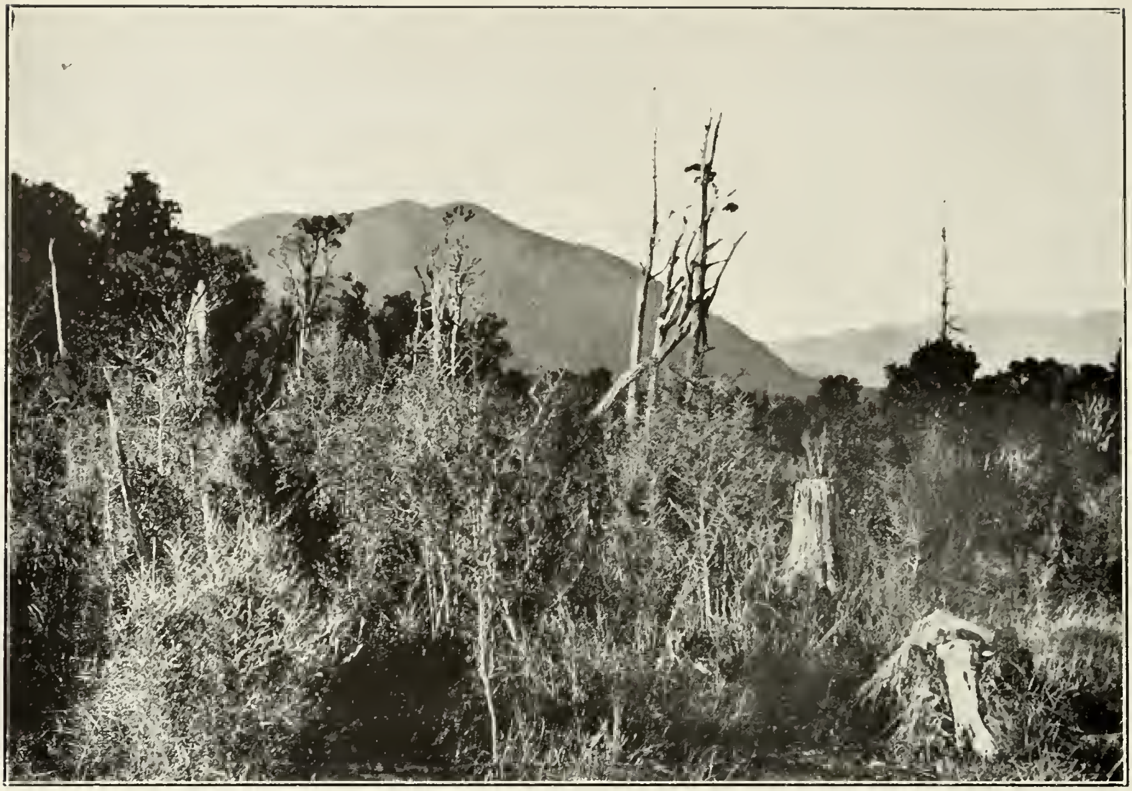
## Methods of Winning Gold.

The early Westland diggers worked the alluvial ground after the methods of the early Californian and Australian miners. When the wash-dirt was close to the surface it was bared by pick and shovel. In deeper ground shafts were sunk, and the wash-dirt driven out. When very rich it might be panned off in the prospecting dish at the nearest stream, or, in the case of beach leads, on the sea-shore. However, the miner generally managed to make a cradle, long-tom, or similar apparatus close to his claim. Sometimes, when water was close at hand, he simply carried it in buckets, but this laborious method required fairly rich material. More often he brought in a supply of water from the nearest stream by means of a water-race, using timber flumes wherever necessary. After the very early days riffle-boxes came into general use. In favourable localities sluicing was practised.

As time went on the rich ground became exhausted and resource was had to hydraulic sluicing, now the general method. This requires an abundant supply of high-pressure water, and in consequence many large and expensive water-races had to be constructed. The gold in the sluicing claims is usually saved by means of sluice-boxes paved with wooden blocks, rounded at the corners and set almost in contact, down which everything except the largest stones passes. The latter are often of enormous size, hundreds of tons in weight, and cause much trouble. They have generally to be broken up by blasting to facilitate removal, the number which have to be removed in this way depending directly on the quantity of water at hand. Notwithstanding their obvious advantages, undercurrent sluices are used only in a few localities--*e.g.*, Humphrey's Gully. When it is considered advisable to clean up, sluicing is stopped and the wooden blocks are removed from the sluicing-boxes a few at a time. The material which has accumulated between the blocks is turned over with a fork and the larger stones ejected. A small stream of water washes most of the fine light material away, and the residuum is carefully panned off. When the last length of sluice-box is reached, the sand, &c., is gathered up and run through a small streaming-box, having its bottom covered with cocoanut matting, plush, blanket, or even split tree-fern trunks. The matting is washed in a tub and the concentrates from it panned off. When the gold is very fine and much black sand is present, mercury is used to save the gold in the final stages of panning off. However, as a rule, this is not very necessary on the West Coast fields.

The operation of working the beach sands on a small scale is known as "black-sanding," because the gold is associated with ironsand (magnetite). The most general way of catching the gold is by means of a small amalgamated copper plate, 3 ft. by 2 ft., at the head of which are two wooden boxes. The whole is erected on a simple frame. The upper box is a hopper for holding the auriferous sand, as it is shovelled in by one man, whilst the lower is kept supplied with sea-water by a second man, who carries it from the water's edge. The water washes the sand over the plate, which catches a certain proportion of the gold. Whenever possible fresh water is brought on to the beach by means of fluming, and "black-sanding" is then often profitable until the deposit is exhausted, or, as is frequently the case, washed away by the waves of the sea. After severe north-westerly gales it is not at all an unusual thing even at the present time to find freshly deposited beach leads, which give handsome returns for a few days until the next severe storm shifts the paystreak out to sea, or so covers the beach with valueless material as to make it uneconomical to work. 1 dwt. per load of twelve barrowfuls is considered to pay wages. The black sand, however, often runs 5 dwt. or even more per load, and occasionally, even yet, extraordinary returns are announced.

The method of obtaining gold from the auriferous drifts by dredging has been in practice for a number of years on the West Coast, but until recently only in a small way. A few years ago, however, the district experienced a dredging boom which was not on the whole beneficial to the mining industry. A large number of dredges were built, but only a very few obtained the results expected of them. Apparently the chief reason for this lack of success has been the difficulty of excavating the material worked owing to the tremendous number of very large boulders, the hardness of the matrix surrounding the boulders, and the number of buried tree-trunks. It it said that alluvium of a richness which would pay well in Otago would not cover expenses on some of the West Coast rivers. Undoubtedly, however, some of the West Coast dredging companies failed owing to over-capitalisation and mismanagement, and some of the dredges originally started by these companies, which were obliged to go into liquidation, are being worked by several private individuals, and, although excavating on the same material, are paying fairly well. Gold is being won by this method now chiefly on the Grey River.



Island Hill, as seen from near the old Kawhaka Inn.

Geological Survey Camp at Milltown.

### AREA DESCRIBED IN THIS BULLETIN.

For the sake of convenience Westland has been subdivided into two sections—the South and North Westland Quadrangles. The work on the latter area has been first undertaken because in general it lies nearer the centres of Westland population, and in consequence any economic results which we might obtain there are more likely to be of immediate benefit. The North Westland Quadrangle has been further subdivided into a number of smaller divisions, each division being of such size as to be conveniently covered geologically in about a year's work, and is made up of a number of survey districts originally laid out by the Lands and Survey Department. The map covering each division is spoken of as "a sheet." The North Westland Quadrangle takes in the whole of the district from the northern boundary of the Westland Province to the Wanganui River, and contains the following sheets named from north to south: the Grey River Sheet, the Haupiri Sheet, the Teremakau Sheet, the Hokitika Sheet, and the Mikonui Sheet. The Hokitika Sheet, which consists of the Survey Districts of Mahinapua, Kanieri, Turiwhate, and Browning's Pass, is the division described in this bulletin, and with it has also been included a small triangular section of the country situated at the head of the Wilberforce River and adjoining Browning's Pass. This addition has been necessitated because of the occurrence therein of auriferous veins, a study of which was urgently needed. In all this bulletin covers an area of about five hundred square miles, and embraces a section from the shore of the Tasman Sea near the mouth of the Hokitika River, eastward to the main crest of the Alps, and across that physical feature down the valley of the Wilberforce to the mouth of the Stewart or Unknown River.

### PLAN OF CONDUCTING WORK.

In carrying out our work every effort has been made to make it as accurate as possible. Though a portion of the area examined we found to be well topographically surveyed, much of it was not done in a sufficiently detailed way for our purpose, and especially in the more rugged alpine part a topographical survey had to be made before the geological work could be undertaken. In making the geological examinations all the larger streams and innumerable smaller watercourses were ascended or descended, the main peaks mounted, and many spurs and ridges followed. It is along the watercourses that the best outcrops are to be observed. Elsewhere a thick surface *débris* or a dense vegetation almost always cloaks the basement rocks, except on the high hills above the tree-line. Even in the creeks themselves, especially on the lower ground, the solid rocks are, for the most part, covered by more recent material. For this reason it is possible that many deposits of economic value may escape even the most careful observer. Whenever exposures of rocks of economic importance were discovered they were made the objects of special scrutiny. Our main endeavour has been not so much to actually locate auriferous veins or other metalliferous deposits, but to delineate the areas in which such may reasonably be expected to be found, and thus facilitate the work of future prospectors.

### LITERATURE RELATING TO WESTLAND GEOLOGY.

1865.—"Report on the West Coast Goldfields," by Sir Julius von Haast; published in Christchurch as a report for the old Provincial Government of Canterbury. In this report Sir Julius von Haast gives a brief but instructive account of the state of the goldfields during the early part of the rush to the Eldorado, a description of the general geology, and a rather more detailed statement of the geological situation of the various auriferous gravels.

1866.—In a "Report on the Headwaters of the River Rakaia," published in Christchurch, and presented to the old Canterbury Provincial Government, Sir Julius von Haast describes the headwaters of the Wilberforce River and the country around Lake Browning—a part of the country considered in the bulletin on the Hokitika Sheet.

1866–67.—In the New Zealand Geological Survey Reports for these years Sir James Hector deals with the West Coast goldfields, and makes some general statements regarding the distribution of the alluvial gold in Westland, and contrasts its mode of occurrence with that of Otago.

1877.—Volume ix of the New Zealand Geological Survey Reports contains a carefully prepared report by Mr. S. Herbert Cox, descriptive of geological explorations conducted by himself and Mr. Alexander McKay in the Westland District during the season of 1875–76. In this report Mr. Cox gives a fuller description of the geological stratigraphy than any previous author, and, in addition, presents much valuable information regarding the occurrence of the auriferous leads and their origin.

1877.—Volume x of the New Zealand Geological Survey Reports includes, in an introduction by Sir James Hector, a brief mention of certain prospecting for coal carried out by the Kanieri Prospecting Association. The same report has a description of explorations for coal at Coal Creek, near Gentle Annie Terrace, by Mr. W. D. Campbell.

1878–79.—The New Zealand Geological Survey Report for these years has some notes by Sir James Hector on the Rangitoto Mine, on dunite on the Upper Hokitika River, and on the then recently discovered goldfields at Kumara, all in the Westland District, but actually outside the area to be described in this bulletin.

1879.—"The Geology of Canterbury and Westland," by Sir Julius von Haast, appeared in book-form in 1879. It contains a charming description of some of the leading physical features of Westland, a general account of its geology, and especial notes regarding its auriferous leads. In addition it has much readable matter relating to timber, soil, and general conditions of Westland.

1881.—In volume xiv of the "Transactions of the New Zealand Institute," Sir Julius von Haast has a paper "On the Geological Structure of the Southern Alps of New Zealand, in the Provinces of Canterbury and Westland."

1883.—Volume xv of the New Zealand Geological Survey Reports has several references to the geology of Westland, though most of them are outside the area considered in this bulletin. In the introduction Sir James Hector describes Mr. S. Herbert Cox's visit to the Woodstock Goldfield and to Humphrey's Gully. Farther on in the report Mr. Cox gives a somewhat detailed account of his investigations at Woodstock—then a newly discovered field—at Humphrey's Gully, and at Ross.

1884.—Volume xvi of the New Zealand Geological Survey Reports contains a report on the sluicing claims in Westland by Mr. S. Herbert Cox.

1886.—In Sir James Hector's concise epitome of New Zealand geology entitled "Outline of New Zealand Geology," a brief mention is made of the foliated schists of Westland.

1886.—"Rambles on the Golden Coast," by R. C Reid, is chiefly a descriptive account of the early history of the West Coast and of its wonderful scenery.

1886.—In volume xix of the "Transactions of the New Zealand Institute," Sir Julius von Haast has a paper entitled "Notes on the Age and Subdivision of the Sedimentary Rocks in the Canterbury Mountains, based upon the Palæontological Researches of Von Ettingshausen." This bears upon the geological sequence of rocks at the head of the Wilberforce River considered within this bulletin on the Hokitika Sheet.

1887.—The "Handbook of New Zealand Mines" contains a somewhat exhaustive account of explorations by the early miners, surveyors, &c., describes the trials of these early pioneers, and gives an account of the distribution of the digging population and of the various auriferous fields. The handbook is a compilation prepared by Mr. Patrick Galvin, under the direction of the then Minister of Mines, the Hon. W. J. M. Larnach.

1892.—In his report for this year Mr. H. A. Gordon, Inspecting Engineer of the Mines Department, has some geological notes regarding the origin of the auriferous leads near Kumara.

1893.—Much the most detailed and instructive report on North Westland is, however, by Mr. Alexander McKay, entitled "Geological Explorations of the Northern Part of Westland." It gives a full description of the general geology, of the occurrence of the auriferous leads, and of the origin of the gold, &c., and is accompanied by a coloured map. Much of it bears especially on the area described in the Hokitika Sheet.

1894.—Volume xxii of the New Zealand Geological Survey Reports has a short note on the Kumara gold drifts of Westland, by Mr. Alexander McKay. Kumara is outside the Hokitika Sheet, but Mr. McKay's description is interesting even in regard to the special area now under description in that he throws some new light on the origin of some of the auriferous gravels. In the same volume Mr. McKay has a longer report relating to Westland. It is entitled "On the Geology of the Northern Part of Westland and the Gold-bearing Drifts between the Teremakau and Mikonui Rivers." In this excellent account Mr. McKay gives notes from previous literature relating to Westland, and, in addition, presents much illuminating information regarding the general geology, the location of the auriferous drifts, and the origin of the gold therein, &c. A coloured map is also included.

1895.—Mr. Alexander McKay has another long and descriptive report which details in part the general geology and economic geology of the Hokitika area. It is entitled "Report on the Geology of the South-west Part of Nelson and the Northern Part of Westland" (C.–13, 1895). A second edition of this report of Mr. McKay's was published in 1897 under separate cover.

1896.—In 1896 Mr. H. A. Gordon and Mr. A. McKay have a report under the heading "Mining Reserves, Nelson and Westland" (C.–9, 1896).

1899.—In his report for this year (C.–9, 1899), in a brief paper entitled "Notes on the Auriferous Ironsands of New Zealand," Mr. McKay makes mention of some of the beach leads at Hokitika and elsewhere.

1900.—In volume iii of the *New Zealand Mines Record* appears a brief account of dredging on the West Coast.

1901.—In his report of 1901 (C.–10, 1901), Mr. Alexander McKay has a short note on the coal at Koiterangi. The paper is entitled "Report on Coal in Koiterangi (Camel Back Hill – Kokatahi Plain – Westland)."

1903.—In "Gold Deposits of New Zealand," a reprint from the *New Zealand Mines Record*, Mr. Alexander McKay, in a number of carefully written pages, briefly describes the auriferous deposits on the West Coast.

1905.—In Dr. P. Marshall's splendid little book on "Geography of New Zealand," many references are made to the physical features of Westland, some of which are within the limits of the Hokitika Sheet.

In addition to these various accounts enumerated, there are many brief references to mining work in Westland appearing in annual reports of the Department of Mines relating to the mining industry, which are not especially mentioned here.

# CHAPTER II.

## GENERAL CULTURE, ETC.

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### Towns and Settlements.

In the early days of the West Coast goldfields settlements sprang up rapidly around each new discovery of the precious metal, the size of each of these communities depending chiefly upon the extent and richness of the find. Many of these settlements shared the universal fate of communities solely dependent on alluvial working, and either diminished greatly in grandeur or actually disappeared altogether.

Hokitika, where one of the first valuable discoveries was made, early became the centre of the goldfield. This was natural, as it was the only point on a stormy coast between the mouth of the Grey River on the north and the Okarito in the south where vessels could hope to enter. Hokitika is still the largest settlement within the sheet of the same name. By the census of 1906 it contained a population of 2,227, though in the palmy days of the goldfields it boasted of ten times that number. However, the golden treasures of the district are by no means exhausted, and a revival of the mining industry may bring renewed prosperity to the decaying town.

The Township of Kanieri, some three miles from Hokitika, with a population of 201 by the census of 1906, was once a very flourishing settlement, and many leads of great richness were worked in its immediate neighbourhood. Now a few old diggers eke out a scant existence on the old workings. Across the Hokitika River from Kanieri is Woodstock, and three-quarters of a mile farther to the southward is the Township of Rimu, together forming almost a continuous settlement along the road running southward from Hokitika. Rimu has a population of 131, and Woodstock of fifty-four. There is still a little sluicing done in this locality, and at least one dredge is working successfully. About a mile northward from Kanieri a single house alone now stands to mark the former active Hau Hau Settlement, where hundreds of diggers once laboured successfully. On Blue Spur Creek is another moribund community, with sluicing and dredging, however, still done on a small scale. Humphrey's Gully is still another dying settlement, formerly a centre of activity. It is situated on the Arahura River, some seven miles above its mouth. One large sluicing claim and several small ones are still working in this locality. On the north side of the Arahura, Fox's, formerly a very rich centre, now shows but scant activity.

Nine miles slightly east of south of Hokitika lies the small straggling but flourishing Township of Kokatahi, which owes its existence not to the diggings, but to the fact that it lies in the middle of the fertile Kokatahi Plain, which forms the flood plain of the three branches of the Kokatahi and of the Hokitika Formerly a very small mining settlement was situated at the junction of the Seven-mile Creek with the Taipo River, about six miles above its mouth. Now, only two tumbled-down huts mark its site. At present settlement of any kind is limited to the narrow coastal plain or the lower parts of the large river valleys, excepting along the main road from Canterbury to the West Coast, which runs through the northern part of the Hokitika Sheet, where there are habitations at remote intervals. In the rugged interior is a huge wilderness quite devoid of any civilisation, though within this area several shelter huts have been erected for various purposes.

### MEANS OF COMMUNICATION.

At present the whole of the District of Westland suffers greatly from lack of communication with the outside world. There are long stretches of harbourless coast, and even the few harbours which do exist within the bars of the main rivers are often shallow and difficult of entry. The railroad from Greymouth to Hokitika, which runs parallel with the coast through the Hokitika Sheet, is being continued southward to Ross, a township south of the Hokitika Sheet. The main coach-road from Canterbury to the Coast enters the Hokitika Sheet on its eastern border, and leaves it about half-way across its northern boundary. This thoroughfare across Arthur's Pass and down the valley of the Teremakau was used by the Maoris for many generations on their migrations to the West Coast in search of the much coveted greenstone. More often, however, in spells of calm weather they coasted along the sea-shore in their canoes from the mouth of the Buller. Before the discovery of the Kumara Goldfield in 1876 the main road to Hokitika, instead of following the Teremakau to the coast, left the edge of the river about ten miles from the sea, and struck westward over some low hills to the valley of the Arahura, and thence onward by Blue Spur to Hokitika, a distance of rather more than fifteen miles from the Teremakau. The eastern portion of this splendid road is now little used, but is still in good repair. The main road from Hokitika southward passes through Kanieri, Woodstock, and Rimu, and traverses a rolling country a few miles east of the sea-shore. From Kanieri Township an excellent road leads up the valley of the Kokatahi, and another extends beyond Lake Kanieri to Milltown, formerly the site of a sawmill. These main arteries of travel through the district are all excellently graded, amply metalled roads, the large rivers and many of the smaller streams being bridged, so that travelling except in the worst storms is particularly good.

The unsettled back country, however, has no roads, the only means of communication through this wilderness being by narrow bridle-tracks. One of these follows the bends of the Arahura on its southern bank from Humphrey's Gully to the foot of Browning's Pass, and is the main route across the country for many miles. It is said that this is also an old path of the Maori warriors. A branch from this track leaves the Arahura about ten miles from Humphrey's Gully, and strikes up on to the Humphrey's Gully Race, which it follows to its junction with the Kanieri Lake Road at Milltown. A broken footpath continues from the end of the Kokatahi Road up the valley of the Styx, and, traversing the river in two places, joins the Arahura Track at the Styx Saddle, some six miles from the base of Browning's Pass. A wagon-road is projected along the Styx Valley to Browning's Pass, and at present this is much the quickest route on foot from the Westland reefs, near Browning's Pass, to the Coast. There is a good track along the Waimea Water-race through the Kawhaka Pass from the old main Canterbury – West Coast Road to the mouth of the Rough Wainihinihi Creek. Another track follows up the valley of the Taipo River on its eastern bank from the Canterbury – West Coast Road to the mouth of Hunt's Creek.

Between the Arahura and Teremakau Rivers, stretching eastwards from the old Canterbury – West Coast Road to the mountains, is an extensive area of rugged mountainous country through which there are absolutely no tracks. A still more inaccessible country lies at the headquarters of the Styx and Kokatahi Rivers. It was these two areas which we found especially hard to explore, because not only were they difficult of entry, but the lofty, broken character of the country made them exceptionally formidable. Fortunately, the valley of the Taipo beyond the end of the track is particularly open, and it formed a good natural highway through this elevated part of the Hokitika Sheet to Pope's Pass, which separates the Taipo from the head of the Wilberforce.

From the Taipo River as a base our side expeditions were carried up the various creeks, entering it from the mountains. Similarly our surveys were extended from the Upper Arahura, Kokatahi, and the Styx. In all of the area drained by these three rivers, excepting up the main track following the Arahura, all camp equipment had to be transported by manual labour. The Westland reefs at the head of the Wilberforce are reached by an unformed track, which follows the Wilberforce River bed from Glenthorne Station in Canterbury. This track can with some difficulty be used by pack-horses following in the main an old road to the base of Browning's Pass, which was constructed in 1885 for the use of the prospectors then engaged at the headquarters of the Wilberforce. In places the road is intact and still well delineated. The Wilberforce Valley can also be reached by the horse-track up the Arahura, and by a foot-track from its end over Browning's Pass.

### WATER-RACES.

In order to handle on a large scale the auriferous gravels in which there was no margin of profit when sluiced by the ordinary methods available to the solitary digger or group of diggers, many water-races have been built by private companies and by the Government. Much the largest of these are the Waimea Water-race, built by the Government, and the Humphrey's Gully Water-race, constructed by Humphrey's Gully Company, and now the property of the Consolidated Goldfields of New Zealand Company.

The Waimea Water-race starts in a small dam which enlarges a natural reservoir at the foot of a steep gorge on the Rough Wainihinihi Creek. The dam is situated at a point 1,075 ft. above sea-level, and from it the water falls over 700 ft. before reaching Goldsborough. From this dam the water-race starts in an excellently constructed canal cut along the northern face of the lower slopes of McArthur Range, from which the race receives several small watercourses in its passage of about a mile to the Kawhaka Creek. The water of the Kawhaka Creek and that brought from the Rough Wainihinihi flows down the channel of the Kawhaka Creek for about three miles and a half, where it enters a large reservoir at a height of 700 ft. above sea-level. From this reservoir the distance to the Waimea Goldfield is about eleven miles. The water is carried practically all the way in narrow open canals, or by wooden or sheet-steel flumes. The longest of the latter is a little over two miles in length, with the steel tube having a diameter of 3 ft. In all thirty-two heads of water are available at the outlet of the race. Its entire length from the Rough Wainihinihi Reservoir to the end is 16½ miles. The cost of construction amounted to £153,000 sterling.

A still longer race is the Humphrey's Gully Race. It has its intake in the Arahura River, about two miles and a half above the Second Gorge, and some fifteen miles in a straight line from Humphrey's Gully, though actually much farther by the serpentine route followed by the water-race. The point of intake is about 840 ft. above sea-level, and the top of the pipe-line at the Humphrey's Gully Claim at the end of Black's Tunnel is over 400 ft. above sea-level, this fall occurring in a distance of sixteen miles following the serpentinous bends of the race. Black's Tunnel is just above the claim now being worked, so there is a vertical fall of from 0 to 150 ft. depending on what part of the present face is being worked. A still greater fall was obtained when faces at lower elevations were worked. Forty sluice-heads or 40 cubic feet of water per second are practically always available, the supply of water being regulated and kept constant by a reservoir of 12 acres surface at Milltown, some six miles in a straight line from Humphrey's Gully. In the main the water is brought in a well-constructed canal to the Milltown Reservoir, the deepest creeks being crossed by steel siphons or wooden fluming. The siphon over Johnston's Creek Gorge is 379 links in length, and is constructed of steel plates, giving an inside diameter of 26 in. The race follows the high bank of the Arahura, leaving that body of water some miles before reaching the Milltown Reservoir, and following the old glacial valley between Pyramid Hill and the slopes of Mount Tuhua. All along its course it receives additional supplies of water brought in by weirs from the numerous mountain creeks which it traverses. About a quarter of a mile below the Milltown Reservoir the race enters a siphon 5970 links in length. This siphon is a huge pipe 36 in. in interior diameter, constructed of No. 12 gauge steel plates. From its outlet the water is again carried in an open flume, save for a tunnel of 424 links at the Doughtown bank, to the beginning of the siphon and tunnel which conveys the water through the Humphrey's

Gully Range to the claim. This siphon of 33 in. pipe has a length of 1133 links, and the tunnel known as Black's Tunnel a length of 2996 links.

In addition to these two prominent water-races there are very many others of greater or lesser importance which have been constructed at considerable expense and trouble, though most of these are now falling into decay with the decline of alluvial mining. It is proposed to extend the Humphrey's Gully Race to Rimu, taking the water across the Hokitika Valley by means of an inverted siphon.

### INHABITANTS.

Mention has already been made of the great influx of gold-diggers in 1865. These pioneers of civilisation quickly made their way all over Westland. Surveyors tell of axe-marks they have found in remote mountain districts where the more modern prospector, notwithstanding the advance of settlement, hardly dreams of going. The diggers were followed by middlemen of all kinds—storekeepers, butchers, saloon-keepers, and others. The area now under consideration may then have had a population of thirty to forty thousand, but in a few years a great decrease, hardly yet checked, took place. To-day the European population of the portion of Westland under consideration, chiefly of British ancestry, is under five thousand, and the total population of the Westland Land District, according to the 1901 census, was 14,506.

The chief occupations of the inhabitants have been already described.

Ever since the discovery of greenstone, and probably before, there have been small Maori settlements on the West Coast, but there are none within the area described in this bulletin, though one exists just outside the boundary at the mouth of the Arahura River.

### FLORA.

One of the most remarkable phenomena on the West Coast is the comparative lowness of the tree-line, considering the mild climate and relatively low latitude. The timber is in general of large size on the lowlands, and gradually decreases in size and depreciates in value upwards. At a height of 3,000 ft. the timber is dwarfed to mountain scrub, which is so dense and matted as to be almost impenetrable. This stunted sub-alpine growth does not endure much above 3,500 ft., where it is replaced by the interesting alpine flora which is so characteristic of the treeless highlands of the southern alpine region. This extends to the limits of perpetual snow. Often while the southern slopes of the hills are snow-covered the protected northern faces show many hardy alpine species in bloom at the close of summer. For example, specimens of a small yellow Ranunculus, a species of Haastia, and a creeping Veronica were found almost on the summit of Mount Tera Tama, at 6,000 ft. above the sea. In the centre of the lofty Alps very few plants, if any, flower above this height in North Westland on the few peaks which rise above that altitude.

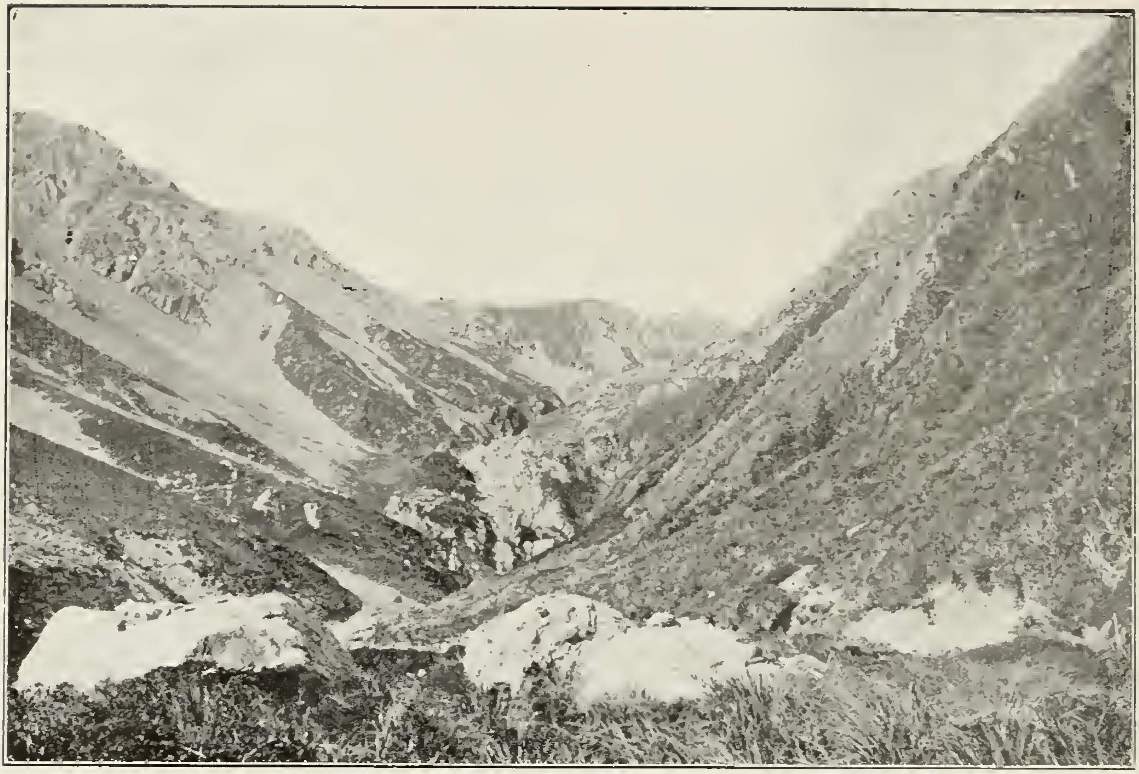
The coastal forest of Westland is one of the district's most magnificent assets, and it exhibits many species of timber-producing trees of great commercial value. Among these may be mentioned the graceful rimu, the stately totara and miro, the tall grey-green kahikatea, the splendid matai, and the red-barked silver-pine. In addition there are many fine trees of other species, which, though not perhaps so important economically as those just mentioned, all lend a charm to the wonderful forest of Westland. The gorgeous rata turns the mountain hillsides into a blaze of blood-red colour during the summer, while stately tree-ferns of several species and the lovely cabbage-tree give the lowland forest an almost tropical splendour. The lower slopes of the hills and often the uplands near the sea are covered with several species of beech, which are not only handsome trees but are in addition valuable as mine timber. Many species of shrubs and creepers abound, forming, as a rule, dense undergrowth which sometimes almost prohibits and always retards travel through the forest. Perhaps the most troublesome of these are the bush lawyer (*Rubus australis*) and the supplejack (*Rhipogonum scandens*), species which are only too well known to every traveller through the dense West Coast bush.

A wealth of ferns and mosses occupies the damper parts of the forest. The ferns vary from lacy filaments, microscopic in size, to huge tree-ferns 25 ft. in height, and with fronds 8 ft. or more in length.

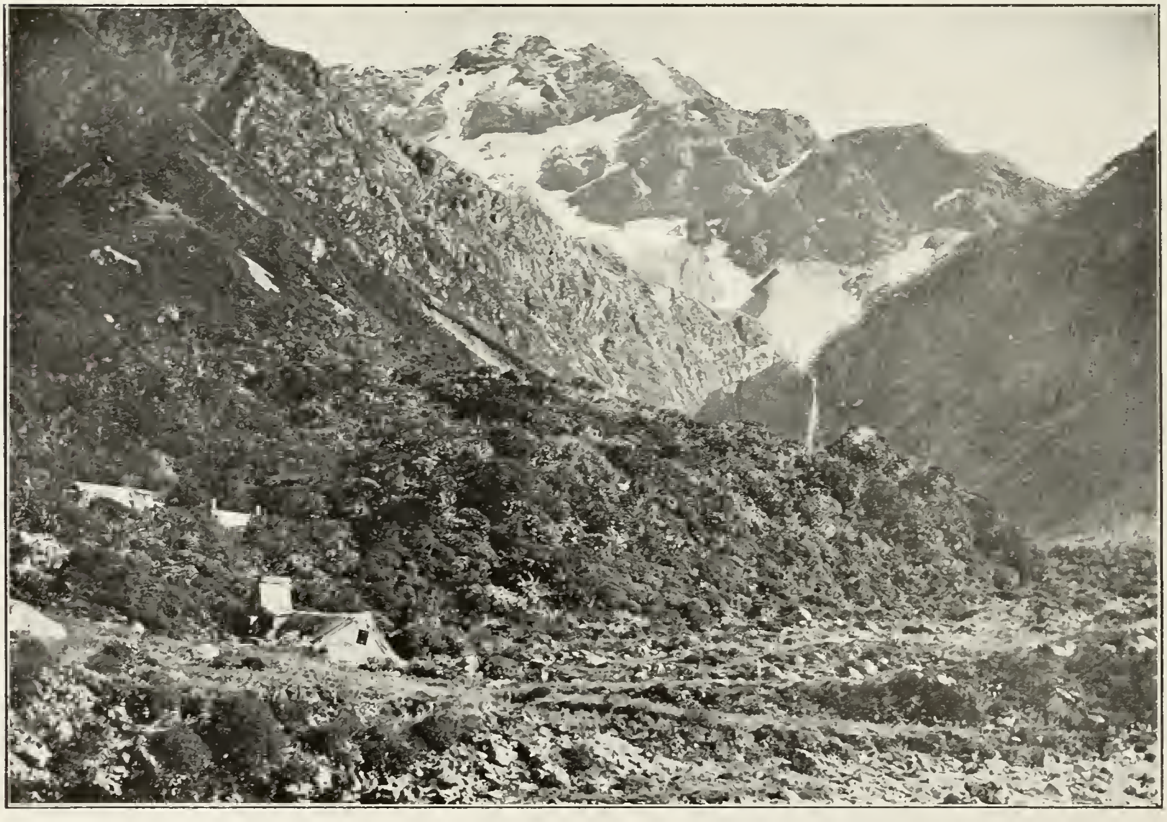
The luxuriant and varied alpine flora turns the snow-free mountain slopes and crests into a veritable garden during the all-too-fleeting summer. Perhaps the most beautiful of all these flowers is the so-called mountain lily (*Ranunculus lyallii*), but of almost equal splendour is the large alpine daisy (*Celmisia coriacea*) and the large yellow buttercup (*Ranunculus godleyanus*). The New Zealand edelweiss (*Helichrysum grandiceps*) is a beautiful light-greenish-white plant, which one finds at high altitudes on many an alpine slope, while grass flats are dotted with Gentians, Senecios, and many other charming species. The occurrence of red snow was observed on a small temporary glacier in Grave Creek, near the head of the Wilberforce. This bears a striking resemblance to *Sphaerella nivalis*, so common in the Swiss Alps.

A list of the common alpine plants found within an area of ten miles from Browning's Pass is appended for the information of those interested in geographical botany. The following is a list of the trees and plants which are of most common occurrence between the sea-level and an altitude of 3,000 ft. on the West Coast. The settler's name, the Maori name, and the botanical name are given for general convenience:—

| Settler's Name. | Maori Name. | Botanical Name. |
|---|---|---|
| Red-pine | Rimu | *Dacrydium cupressinum.* |
| Silver-pine | .. | *Dacrydium westlandicum.* |
| White-pine | Kahikatea | *Podocarpus dacrydiodes.* |
| Totara | Totara | *Podocarpus totara.* |
| Black-pine | Matai | *Podocarpus spicatus.* |
| Miro | Miro | *Podocarpus ferruginea.* |
| Cedar | Kawhaka | *Librocedrus bidwillii.* |
| Rata | Rata | *Metrosideros lucida.* |
| Red-birch | .. | *Nothofagus fusca.* |
| White-birch | Tawhero | *Nothofagus menziesii.* |
| Black-birch | Tawhai | *Nothofagus solandri.* |
| Hinau | Hinau | *Eleocarpus hookeri.* |
| Tanekaha | Tanekaha | *Phyllocladus alpinus.* |
| Tea-tree | Manuka | *Leptospermum scoparium.* |
| Fuchsia | Kotukutuku | *Fuchsia excorticata.* |
| Wine-berry | Makomako | *Aristotelia racemosa.* |
| Broadleaf | Puka | *Griselinia lucida.* |
| Kowhai | Kowhai | *Sophora tetraptera.* |
| .. | Putaputaweta | *Carpodetus serratus.* |
| Koromiko | Koromiko | *Veronica* (many species). |
| Tutu | Tutu | *Coriaria ruscifolia.* |
| Cabbage-tree | Ti | *Cordyline australis.* |
| Mountain cabbage-tree | Toi | *Cordyline indivisa.* |
| Matipo | Matipo | *Pittosporum eugenioides.* |
| Lacebark | Whauwhi | *Gaya lyallii.* |
| Stinkwood | Hupiro | *Coprosma fœtidissima.* |
| Karamu | Karamu | *Coprosma lucida.* |
| Green-bark | Porokaiwhiri | *Hedycarya dentata.* |
| Red-birch | Kamahi | *Weinmannia racemosa.* |
| Five-finger | Patete | *Schefflera digitata.* |
| King-fern | Mamauku | *Cyathea medullaris.* |
| Tree-fern | Ponga | *Cyathea dealbata.* |
| Tree-fern | Wheki-ponga | *Dicksonia antarctica.* |
| Lancewood | Horoeka | *Pseudopanax crassifolium* |



Browning's Pass, from near the Head of Arahura River.



Hamer Falls, and the Valley of the Upper Wilberforce.

*Geological Bulletin.*]

New Zealand flax (*Phormium tenax*) is a plant of general occurrence all over Westland. It is especially common in the swampier portions of the Kokatahi Plains, where is has been prepared for commercial use.

As in other parts of New Zealand, a large number of European trees, shrubs, grasses, &c., have been acclimatised, but the native vegetation has not yet been displaced to any great extent except in artificial clearings.

### TIMBER.

The timber industry has recently made great advances in Westland owing to greater facilities for transportation than formerly, and because of the depletion of timber-producing forest in other parts of the colony. Small sawmills are to be frequently seen near the coast, and it seems very certain, with the still better conditions that will come with the opening-up of a railway to Canterbury, and an improved harbour at Greymouth now projected, that the timber industry will make rapid advances in this part of New Zealand. Perhaps the most valuable timber for export is red-pine, though silver-pine is in great demand locally, owing to its great durability for railway sleepers and in the construction of bridges, water-races, flumes, and foundations. White-pine is also used locally in the manufacture of butter-boxes, and a greater supply will be necessitated with the expected improvement of the dairying industry. It is also exported in considerable quantities. Totara and black-pine are other valuable forest trees used as timber, though chiefly for local consumption. There are fine patches of red and white pine along the lower part of the Taipo River below the entrance of Hunt's Creek, and much excellent mixed timber bordering the Styx and the Arahura. The Humphrey's Gully Range, the Kawhaka Plain, and the country near Kawhaka Pass are well wooded, and exhibit much good marketable timber.

### FAUNA.

The wilderness of Westland shields from extinction many an interesting bird which has almost disappeared in other parts of New Zealand. In fact, bird-life seems to be especially prolific in Westland, as compared with other parts of the colony. One frequently sees the pigeon or kereru (*Carpophaga novæ-zealandiæ*), the New Zealand fantails (*Rhipidura fuliginosa* and *Rhipidura flabellifera*), the New Zealand tomtit (*Myiomoira macrocephala*), the bell-bird or makomako (*Anthornis melanura*), the parson-bird or tui (*Prosthemadera novæ-zealandiæ*), and the blight-bird (*Zosterops lateralis*). The green parrakeet (*Platycercus alpinus*), which formerly congregated on the West Coast in great numbers, is now rarely seen, but occasionally one catches a glimpse of its bright plumage or hears its sharp note in the depths of the forest. It is said that this bird only appears at long intervals, coming then in great flights. The New Zealand robin (*Miro albifrons*) is but rarely seen on the West Coast.

One of the most wonderful birds of Westland is the kea (*Nestor notabilis*)—the voracious parrot which is said to have developed an extraordinary and not inherited taste for young sheep's flesh, especially the kidneys. This beautiful dull-green bird with red underwings is frequently seen in the mountains betwen 2,000 ft. and 5,000 ft., though but seldom observed at lower levels. It was noticed to be especially common around Browning's Pass and near the headquarters of the Taipo, where it would swoop down very close to us with a hoarse strident shriek, and strut about apparently without fear at our close proximity.

The weka or wood-hen (*Ocydromus australis*) abounds in great numbers in the interior, and may be seen up to the edge of the tree-line. It is everywhere a most inquisitive bird, but this dominating characteristic becomes more and more apparent the more remote it is seen from settled localities. It is an ungainly bird, though its rich brown, variegated plumage gives it a rather pleasing appearance. Its repertoire of sounds is astonishing. Like the kakapo (*Stringops habroptilus*) and kiwi (*Apteryx australis*), it is a flightless bird.

The kiwi is almost unknown near the coast, but in the interior, especially on the Taipo, though the bird is seldom seen, the curious call of the male usually answered by the cry of the female notifies one of its presence in some numbers, and, of course, its nocturnal habits protect it from observation. The word "kiwi" as well as "weka" is onomatopœic.

The morepork, or New Zealand owl (*Spiloglaux novæ-zealandiæ*) is heard everywhere at night; though hidden in the branches it is seldom seen in the daytime, as, like the kiwi, its habits are nocturnal. The name "morepork" is a very good imitation of its curious call.

In the swamps and lowlands, especially on the Kokatahi Plain, one sometimes sees the dark-blue-feathered red-beaked pukeko or swamp-hen (*Porphyrio melanotus*), and on the lakes and rivers may be seen grey ducks (*Anas superciliosa*), the beautiful paradise duck (*Casarca variegata*), teal (*Fuligula novæ-zealandiæ*), several species of cormorant or shag (*Phalacrocorax brevirostris*, &c.), kingfisher (*Halycon vagons*), &c. In the mountain rivers and streams the mountain duck (*Hymenolæmus malacorhynchus*) is still common, though this handsome greyish-blue bird is said to be decreasing in numbers. On the sea-shore the usual New Zealand species of gull, snipe, and sand-piper are but moderately common, the scarcity being due apparently to a lack of food. The koheperoa or long-tailed cuckoo (*Eudynamis taitensis*) is sometimes seen and heard.

Besides birds the only other species of land vertebrates are one or two kinds of lizards.

Native fish, except eels (these are only visible in the warmer waters), are not very abundant in the rivers. Grayling and catfish are sometimes seen. In the spring shoals of whitebait make their way up the rivers in immense numbers. Flounders are rather scarce, but a few are obtained near the river-mouths. Owing to the lack of easily accessible harbours there is practically no sea-fishing in Westland.

Insect life is fairly abundant, including various kinds of butterflies, moths, spiders, a variety of caterpillars, ants, &c. Among objectionable insects are wetas, mosquitoes, sandflies, and the odious bluebottle fly. The latter is a most ubiquitous insect, and on several occasions was observed above the level of perpetual snow even when the temperature stood but little above freezing-point.

Introduced animal life includes the usual farm and domestic animals, together with rabbits, weasels, red deer, rats, mice, &c. Some years ago some Canadian moose were liberated near the forks of the Kokatahi. They have not been seen for some time, though it is thought that they are still in existence.

A large number of European birds have been acclimatised. Among these may be mentioned black swan (*Cygnus atratus*) from Australia, sparrow (*Passer domesticus*), lark (*Alauda arvensis*), goldfinch (*Carduelis elegans*), yellow-hammer (*Emberiza citrinella*), blackbird (*Turdus merula*), starling (*Sternus vulgaris*), and thrush (*Turdus musicus*). Some of these birds have developed instincts quite or nearly unknown in Europe. For example, the blackbird and thrush, especially the former, are in New Zealand voracious devourers of fruit.

Trout are becoming numerous in the rivers and lakes. In a few years there will no doubt be excellent trout-fishing in Westland waters.

### SOIL AND AGRICULTURE.

Owing to the fact that by far the greater part of Westland is mountainous, only a small proportion is suitable for farming. Even on the more level and lower parts much of the soil is too light for the growth of cereals, though often, owing to the mild, moist climate, it supports really rich pasture. The richest land is to be found along the flood plains of the various rivers, on or near the coastal belt, especially where the underlying soil is derived from the decay of argillaceous rather than quartzose or arenaceous rocks. By far the most extensive tract of arable land is the Kokatahi Plain, which is made up of the flood plains of the Hokitika and the several tributaries of the Kokatahi at and near their junction. Here is situated a relatively large area of rich fertile soil, though much of it is low and swampy and at present unfit for agriculture. Most of this part of the district is cleared, but towards the edge of the mountains there is still some good land on which the forest is standing. With the draining of the swamps and the felling of the bush much more land might be opened up to advantage.

The lower flood plain of the Arahura near the coast shows some splendid land, on which prosperous farms are situated. Further up the river, beyond the present limits of settlement, there are good patches of river flats, almost to the head of the stream. These patches are always green, and during the summer are covered with a heavy sward of grass. In addition to these river flats, some of the higher terraces along the river exhibit good soil. The most notable is the extensive flat, of which very little is yet cleared, at Olsen's Clearing, about twelve miles from Milltown. The lower part of the Wainihinihi and its tributary, Macpherson's Creek, are bordered by some good natural clearings, which could be extended to advantage by the removal of some of the adjoining forest. There is little settlement close to the sea-shore, but where the gravels are not reassorted by fluviatile action the soil can hardly be said to be sufficiently rich to repay cultivation.

The broad valley of the Teremakau is bordered in places by fertile, cultivated fields, though there is comparatively little artificially cleared land. Fitzgerald's clearing at the mouth of the Rough Wainihinihi is much the most extensive. Here good crops of hardy cereals and fat healthy cattle testify to what can be done in the farming line in this part of the district. Above the gorge of the Taipo there are many small areas of flat river-bottom covered with a good growth of grass, green practically the whole year round, which are eminently suitable for cattle-grazing. These areas extend up the river a short distance beyond Hura Creek, and some are at present utilised. Only very small patches of land have as yet been cleared along the river, though there are small areas on which the bush could be felled to advantage. Above the tree-line and extending downwards from the snow-covered tops, on many of the ridges are flats and slopes covered with a rich growth of tussock. In general this tussock-covered country lies between the altitudes of 3,000 ft. and 5,000 ft. It is very suitable for grazing the hardier varieties of sheep, as much of it is free from snow during the greater part of the year. The largest stretches of this grassy mountainous country are situated on the Griffin and Tera Tama Ranges, but there are smaller patches at the head of the Taipo and Arahura Rivers, and on the Styx Saddle.

All of the fruits of the temperate zone, together with all ordinary vegetables and cereals, grow in Westland. Grass grows luxuriantly in almost every clearing, and forms abundant food for stock practically the whole year round. With care also, oats, turnips, cabbages, and other well-known vegetables are good crops. Considerable areas of Westland are suitable for pasturage of sheep and cattle, while some parts are better adapted to dairying—an industry capable of much development. Undoubtedly there is much land in the area covered by the Hokitika Sheet still to be opened. Bushfelling is expensive, but the establishment of dairy factories is already raising the price of land and giving a needed stimulus to the clearing of the forest.

## CLIMATE.

Perhaps no feature of Westland is more grossly maligned in other parts of New Zealand than its climate. It is generally represented as a land of practically unceasing rain—so wet as to be unfit for settlement. A few months on the Coast, however, quickly dispels this erroneous conception. The climate, of course, is very often exceedingly wet, as will be seen by a glance at the rainfall of

Hokitika in the meteorological tables. However, there are spells of beautiful clear calm weather in Westland equalling those in other parts of the colony. Day after day for a week or more the sun will set in a cloudless sky, with wonderful colour effects unsurpassed elsewhere in New Zealand. It is impossible to describe the marvellous variety of these changing tints as the colour changes from yellow to orange, from orange to crimson, then deepens to exquisite shades of purple, saffron, and even on rare occasions to a curious greenish blue. Another charming feature of the Westland climate is the infrequency of high winds, as compared with the Canterbury Plains on the east side of the Alps.

According to the report of the Meteorological Observer (the Rev. D. C. Bates), based on observations made at Hokitika for the last twenty-six years, rain falls on the average on 177 days in the year; but this is very little more than at Wellington, where, according to the same authority, the average number of rainy days per annum, as judged from a record of forty-one years, is 166. However, the actual amount of rainfall at Hokitika is greatly in excess of that of Wellington. At Hokitika the average annual rainfall amounts to no less than 117 in., while at Wellington it is only 51 in. Apparently, on the whole, the rainfall is much more evenly distributed at Hokitika than at Wellington. The winter is drier in Westland, but the summer is damper than in Wellington.

The driest month in Westland is February, while the wettest month is October, when the prevailing westerly winds precipitate their heavy quota of moisture on the western slopes of the Alps. Of course, away from the coastal belt in the mountainous country the rainfall is much more excessive, and the rainy days more frequent. Often in the heart of the mountains the rain may be coming down in torrents, while but a short distance away it may be merely showery, and on the sea-shore it may be quite fine weather. This localisation of especially rainy areas is often very noticeable. For example, while camped at Kawhaka Pass, between Mount Turiwhate and Island Hill, during the month of September we had almost continual wet weather, while but a few miles away on the Christchurch Road this spell of wet weather was broken by many hours of sunshine.

In the mountains snow, of course, replaces the rain in winter, and even down to an altitude of about 2,500 ft. snow-flurries may occur at any time, though they are not usual in summer. Snow very rarely falls on the coast, but away from the influences of the sea, below 2,500 ft., though snowfalls are rare, they are by no means unknown, and, as a rule, occur nearly every winter, their frequency and the amount of snow actually on the ground increasing with the greater altitude. In the heart of the mountains the snow-line is considerably depressed—the snow lies deeper and longer than it does at the same altitude nearer the coast, and the climate is in consequence colder. This feature greatly retards the advancement of geological work. This year (1906)—an unusually severe and inclement season—the snow did not all leave Browning's Pass (altitude 4,510 ft.), and Pope's Pass (altitude 5,290 ft.) was almost entirely covered, even at the time of maximum freedom from snow. In ordinary seasons Browning's Pass is, it is said, practically free from snow early in December. This year there were snowfalls on the Wilberforce at an altitude of 3,000 ft. every month during the summer, and a remarkably heavy fall in the first week in April, which covered Browning's Pass with over 1 ft. of snow, and whitened the ground as far down the Arahura as the Pyramids (3,110 ft.), and down the Taipo River to a similar altitude.

In the following table, showing the number of rainy days each month and during the year, and the monthly and annual temperatures, similar meteorological statistics relating to Christchurch and Wellington are also inserted for purpose of comparison*:—

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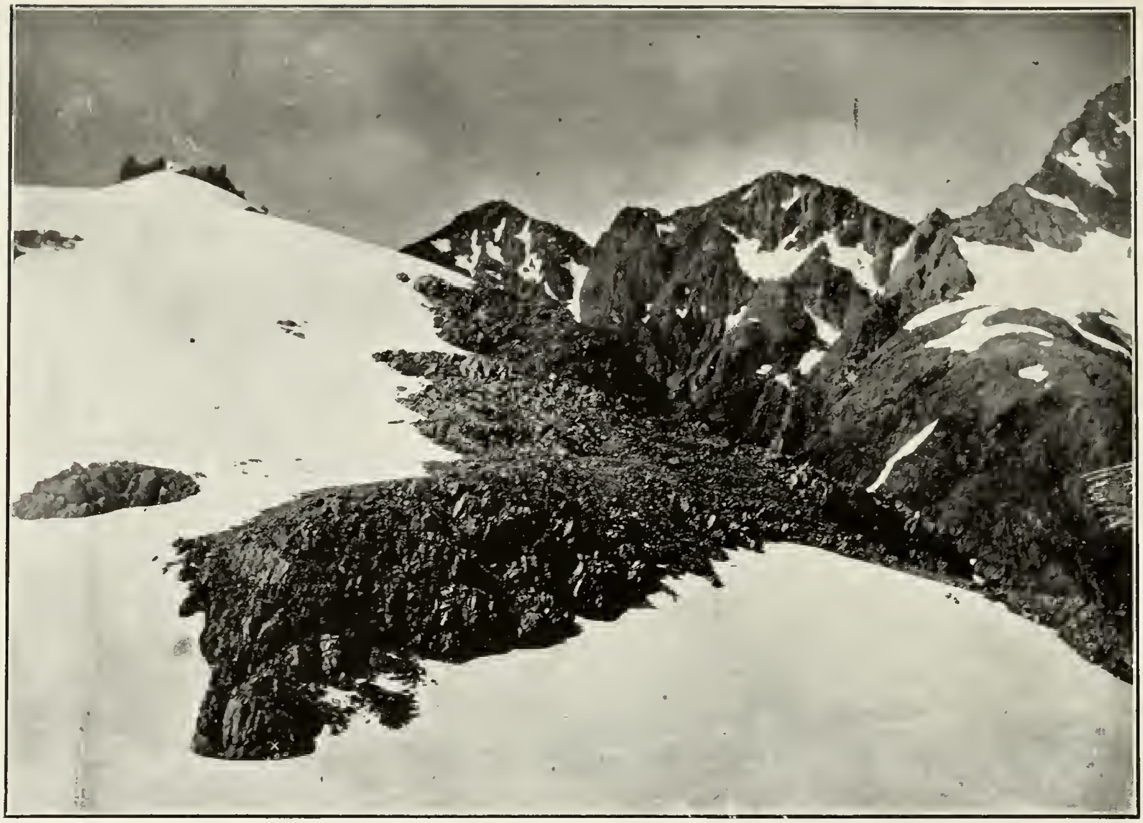
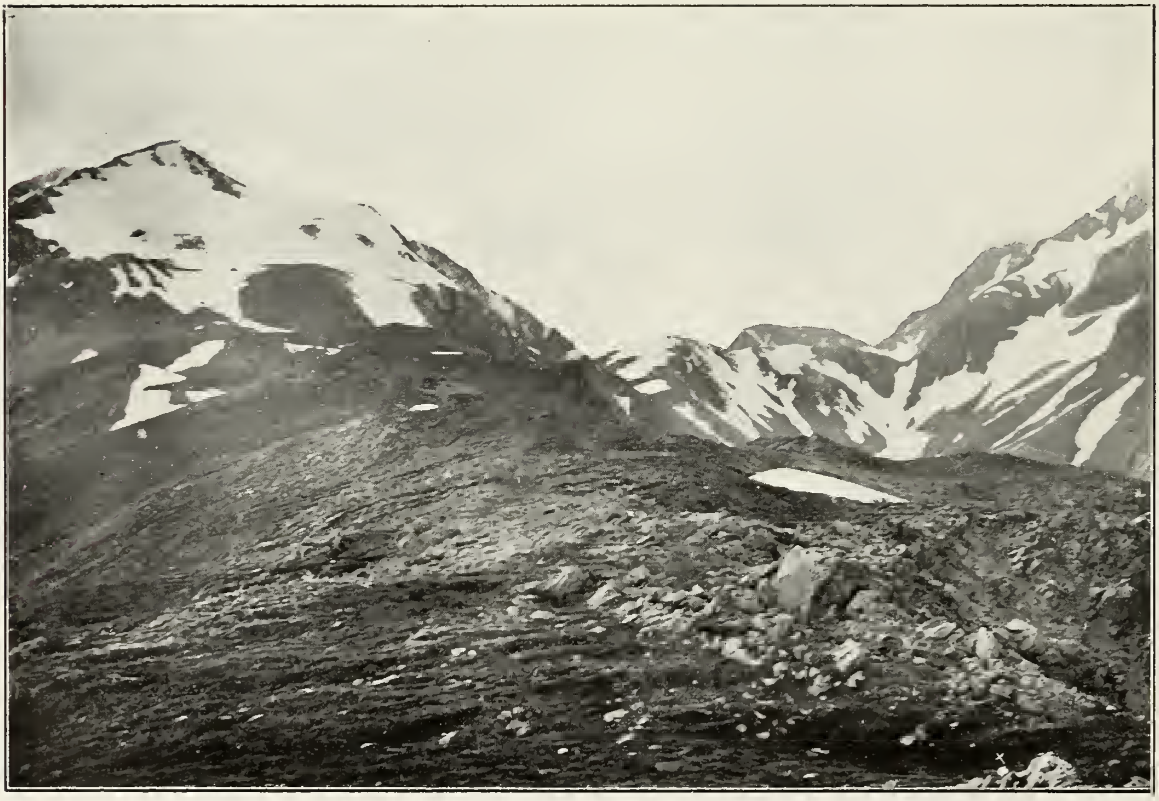
* All these meteorological data have been obtained for us through the courtesy of the Rev. D. C. Bates, Meteorological Observer.



Mount Pope and the Rosamond Ridge, as seen from Pope's Pass.



Mount Harman and the Rosamond Ridge, from Browning's Pass.

*Results of Observations.—Hokitika, Twenty-six Years; Wellington, Forty-one Years; and Canterbury, Thirty-nine Years.*

*Mean Number of Days with Rain (0 01 in. or more).*

| | Jan. | Feb. | Mar. | April. | May. | June. | July. |
|---|---|---|---|---|---|---|---|
| Hokitika ... ... ... | 15 | 11 | 14 | 14 | 16 | 15 | 16 |
| Wellington ... ... ... | 10 | 9 | 11 | 13 | 16 | 17 | 18 |
| Christchurch ... ... | 9 | 8 | 10 | 9 | 11 | 12 | 13 |

| | Aug. | Sept. | Oct. | Nov. | Dec. | Annual Mean Total. |
|---|---|---|---|---|---|---|
| Hokitika ... ... ... | 12 | 12 | 18 | 17 | 17 | 177 |
| Wellington ... ... ... | 17 | 16 | 14 | 13 | 12 | 166 |
| Christchurch ... ... | 12 | 10 | 10 | 9 | 9 | 122 |

*Mean Temperature, Air in Shade, in Degrees Fahrenheit.*

| | Jan. | Feb. | Mar. | April. | May. | June. | July. |
|---|---|---|---|---|---|---|---|
| Hokitika ... ... ... | 60·1 | 60·7 | 58·3 | 56·1 | 51·4 | 46·8 | 43·5 |
| Wellington ... ... ... | 62·6 | 62·4 | 60·5 | 56·9 | 52·8 | 49·5 | 47·6 |
| Christchurch ... ... | 62·0 | 61·2 | 57·9 | 53·7 | 47·7 | 43·8 | 42·5 |

| | Aug. | Sept. | Oct. | Nov. | Dec. | Annual Mean Temperature. |
|---|---|---|---|---|---|---|
| Hokitika ... ... ... | 46·1 | 49·9 | 52·6 | 55·2 | 59·1 | 53¼ |
| Wellington ... ... ... | 48·5 | 51·5 | 54·3 | 57·0 | 60·7 | 55¼ |
| Christchurch ... ... | 44·4 | 48·9 | 52·8 | 56·2 | 60·1 | 52·8 |

The following tabulations of the prevailing winds at Hokitika are of interest:—

*Percentage of Directions of Winds from Annual Returns for Years 1896–1905.*

| Direction ... ... | N. | N.E. | E. | S.E. | S. | S.W. | W. | N.W. |
|---|---|---|---|---|---|---|---|---|
| Percentage ... ... | 1 | 4 | 25 | 1 | 0 | 46 | 1 | 22 |

The prevailing wind—south-west—is thus seen to have a frequency almost equal to that of east and north-east taken together, while other directions are of small account. The conformation of the country probably accounts in the main for this peculiar arrangement.

*Table showing Differences between the Winds of Months of January and July (Summer and Winter).*

| Direction ... ... | N. | N.E. | E. | S.E. | S. | S.W. | W. | N.W. |
|---|---|---|---|---|---|---|---|---|
| January percentage ... | 0 | 2 | 0 | 0 | 0 | 72 | 1 | 25 |
| July " .. | 0 | 6 | 55 | 2 | 0 | 20 | 0 | 17 |

*Table showing the Winds of the Driest Month of the Year (February), and the Wettest Month (October).*

| Direction ... ... | N. | N.E. | E. | S.E. | S. | S.W. | W. | N.W. |
|---|---|---|---|---|---|---|---|---|
| February percentage... | 1 | 3 | 0 | 1 | 0 | 71 | 1 | 23 |
| October " ... | 2 | 3 | 8 | 0 | 0 | 61 | 3 | 23 |

## SCENERY.

It is very difficult in the brief compass which space allows in this report to do anything like adequate justice to the marvellous variety and wonderful beauty of the scenery of Westland. Near the coast the rivers and creeks ramify through a forest of almost tropical splendour—a forest of stately rimus and kahikateas, of gorgeous tree-ferns and innumerable splendid creepers. Here and there are brown-watered ponds reflecting the trees which surround them. Farther inland the foothills are bright during the summer with a wealth of crimson rata, while the river courses run now in deep wild gorges, again shoot over a waterfall or bubble down a boulder-strewn rapid. In the remote hinterland the alpine scenery is superb. Here one gets the lofty snow-clad peaks, the dark jagged rocky crests and spurs, the deep-blue crevassed glaciers, the numerous waterfalls, and many other features of exquisite beauty. Often all or several of these features are to be observed in the same scene. From the shades of magnificent trees one may look down upon a glacier, and up on to the whitened crests of the Southern Alps.

The view from the beach near Hokitika on a clear calm day is one not soon to be forgotten. In the background is the splendid panorama of the Southern Alps, stretching northward from the magnificent summit of Mount Cook to the crests of Mount Rolleston and Mount Alexander. In the foreground dark-green outliers stand out clearly against the lofty serrate alpine ridge behind, while nearer at hand is ever the matchless varied forest of Westland.

A splendid view can be obtained from Mount Tuhua, which is reached from Lake Kanieri by a good mountain-track. Being apart from the main alpine chain, its position is an excellent one from which to view the surrounding country and the alpine chain. An equally fine and somewhat more extensive view is that to be seen from Mount Turiwhate, which is easily reached from the Christchurch Road. However, probably by far the best view within the area is that obtained from Mount Tera Tama, a stately dome which raises its snow-covered top some 6,084 ft. above sea-level, and over 1,000 ft. above most of the surrounding mountains. The serrate snow-covered crest of the Alps is visible from the lofty buttress of Mount Cook northward to and beyond the Spenser Mountains. The alpine chain shuts off the view to the eastward, but in the nearer foreground stand out a maze of peaks, many of which have their tops snow-clad. Northward the view ends at the Paparoas, while Lake Brunner and the valley of the Teremakau are visible close at hand. Towards the north-westward may be seen the broad expanse of the Tasman Sea, the rolling lowlands bordering it, and nearer at hand Mount Turiwhate and Mount Tuhua, the valley of the Arahura, and the sharp crests and ridges of the Griffin and McArthur Ranges deeply incised by the numerous creeks which flow to the Arahura, Taipo, or Teremakau. From Mount Tera Tama practically the whole area of the Hokitika Sheet is splendidly disclosed panoramically, and the exquisite view obtained from its summit amply repays the somewhat arduous climb. It is probably most easily reached from the head of Freitas Creek, though our route was from the most northern branch of the Hura Creek, and perhaps a shorter though much more difficult path is by the main fork of Dunn's Creek.

There is no finer gem in New Zealand scenery than Lake Kanieri, with lovely wooded hills surrounding its clear watered surface, and ever the rugged grandeur of the snowy Alps in the background. Lake Mahinapua is another feature of rare beauty which is much visited by tourists to the West Coast.

# CHAPTER III.

## GEOLOGIC HISTORY.

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### Geological Sequence.

Probably the oldest rocks at present visible in any considerable mass within the Hokitika Sheet consist of mica, amphibole, epidote, and quartz schists, and phyllites, which are overlain apparently conformably by rocks which are possibly their less metamorphosed equivalents—sandstones, grauwackes, and argillites. The whole make up what we are tentatively calling the Arahura series.

The sandstones, grauwackes, and argillites form the main mass of the Southern Alps, while the various schists compose the outlying broken ridges, the summit of which represent physiographically the Wainihinihi peneplain. West of this is a belt of granitic rocks containing also some gneissoid rocks. The latter may be the remnants of rocks even more ancient than the metamorphic schists, though the granite rocks are undoubtedly more recent than any rocks of the Arahura series. As will be explained later on in this bulletin, the granites and the small amount of gneiss are inseparable, and are classed together as the Tuhua formation.

Running through the Arahura series and occupying approximately a median position in the area of extreme metamorphism is a narrow belt of igneous rocks which are irruptive into them. These are called the Pounamu formation.

Lying west of the main granite belt and in part enclosed between it and a smaller granite boss are a series of mica schists, grauwackes, sandstones, argillites, and conglomerates, which have been classified together as the Kanieri series. The Kanieri series may be in part or wholly contemporaneous with the younger portion of the Arahura series, but we have only lithological evidence on which to base any comparisons, and so, in the absence of palæontological data, no definite correlation is in this bulletin attempted.

The main mass of the Kanieri series consists of grauwackes and argillites, generally but slightly altered. As the main granite belt is approached a development of metamorphic minerals is distinctly noticeable, until finally in close contact with the igneous rocks crystalline schists appear. Every evidence points to the fact that the latter are the metamorphic equivalents of the grauwackes and argillites, and are practically a continuous series. On the western border of the Kanieri series, however, appear soft ferruginous sandstones and argillites, with a narrow belt of conglomerate at their base, which seem to differ in several respects from the other rocks of the Kanieri series, and may be quite distinct therefrom, the conglomerate representing an unconformity. These points will be elaborated in detail later on in this report.

Above the Kanieri rocks and separated from them by a very decided unconformity is a series of coal-bearing rocks, very poorly represented in the Hokitika Sheet. These we have called the Koiterangi series, and, according to various palæontological authorities, they are considered as of Cretaceous, Cretaceo-tertiary, and early Tertiary age.

Above the Koiterangi series lies a great thickness of but slightly disturbed marine clays, which merge upwards into sandstones and finally are replaced by well-rolled gravels. The clays and sandstones are called the "Blue Bottom," and contain undoubted Miocene fossils, while the stratified gravels are known as the "Humphrey's Gully beds." Overlying the Humphrey's Gully beds are thick deposits of unstratified morainic *débris* (the morainic gravels)—stratified river gravels and stratified marine gravels. These were probably all forming contemporaneously, and are still forming in certain parts of the area covered by this report. Their various relations will be detailed in another chapter.

The following statement in tabular form represents the geological sequence:—

| McKay's Classification. | Nomenclature in Present Bulletin. | Age. |
|---|---|---|
| Matai series (Carboniferous), Te Anau series (Devonian), and earlier | Arahura series ... ... | Early Mesozoic (?) and earlier. |
| Matai series (Carboniferous) ... | Kanieri series ... ... | Early Mesozoic (?) or Carboniferous (?). |
| Magnesian belt ... ... | Pounamu series ... ... | Post Arahura series. |
| Granites, gneiss, and basic dykes | Tuhua formation; unconformity | Post Arahura series. |
| Cretaceo-tertiary ... ... | Koiterangi series; unconformity | Early Tertiary or Upper Cretaceous. |
| Blue Bottom ... ... | Blue Bottom; slight unconformity | Miocene. |
| Humphrey's Gully beds ... | Humphrey's Gully beds ... | Pliocene (?) |
| Morainic beds ... ... | Morainic gravels ... ... | Upper Pliocene and Pleistocene. |
| Marine gravels ... ... | Marine gravels ... ... | Pleistocene and Recent. |
| Fluviatile gravels ... ... | Fluviatile gravels ... ... | Pleistocene and Recent. |

NOTE.—Some of the marine and fluviatile gravels were laid down, according to Mr. McKay, prior to the advance of the glaciers. The authors of the present bulletin consider that some of the glacial *débris* is undoubtedly more recent than the earlier marine and fluviatile gravels.

### GEOLOGICAL HISTORY.

The authors of the present bulletin feel reticence in attempting a description of the geological history of the many changes which have affected the Hokitika area, in common with a large portion of New Zealand, after an investigation of so small a part of the country. The following disquisition is considered as being in part hypothetical, and distinctly subject to future revision.

In remote geological time a huge ancient land-mass probably stretched far to the westward of the present western boundary of the South Island of New Zealand. The rocks of this ancient land have apparently completely disappeared, though it is possible that the remnants of gneissoid rock included within the existing granite may represent lithologically this former continent. This ancient land must, in fact, have been chiefly granitic or gneissoid, as judged by the character of the sedimentary rocks which are derived from it.

To the south-eastward on a gradually sinking shore was deposited an immense thickness of grits, sandstones, argillites, and grauwackes. The deposition of this huge thickness of rocks probably extended over many geological periods, and, though evidences of minor changes of level are exhibited, there are no proofs shown within them inside the compass of the Hokitika Sheet which indicate any great unconformity.

Though we quite realise that this huge thickness of sediments should be subdivided if either palæontological or structural data were at hand to make this separation, without this material no separation by age is at present possible. Thus the only subdivision that is possible is an arbitrary and temporary one subject to future alteration. Later on in this report it will be detailed why we have classified the great thickness of sediments into the Arahura and Kanieri series. Here it may be stated that in general it is supposed that the Kanieri series corresponds in age to the upper part of the Arahura series, though it is freely admitted that this is hypothetical. Again, it is undoubted that the lower part of the Arahura series has suffered regional metamorphism to a degree very much greater than either the Kanieri series or the upper part of the Arahura series, and hence it may reasonably be imagined that some decided orogenic movement took place in the early sediments which did not affect the latter. The thin beds of conglomerate in the Kanieri series may represent minor unconformity, but they are apparently of the nature of what Professor van Hise calls " intra-formational unconformity " rather than a great structural break.

At the close of the long extended time in which the Arahura series and Kanieri series were deposited, an orogenic movement started which elevated the area on the south-east side of the ancient land above the sea. The elevation of the Kanieri rocks and probably also the Arahura rocks did not consist in a mere elevation above sea-level, but in plication of the strata as well. During this plication, and supposedly in part the direct result of it, came the intrusion of the great masses of granite. It is possible that the granites as we now see them may be the re-fused equivalents of the rocks of the ancient land. The numerous quartz veins in the Arahura and Kanieri series are probably the result of long-continued hydrothermal action caused by the granite intrusion, while the pegmatite dykes within the granite represent aqueo-igneous action during the time that the magma of the latter was still warm.

In Upper Cretaceous or early Tertiary times the land to the north-westward of the new land-mass depressed, and thick beds of conglomerates, grits, sandstones, and coal were formed, the latter probably in a swamp with thick vegetation close to the sea-margin. Further depressions with deeper water permitted the deposition of beds of limestone on top of the coal-measures. At the close of this period came another period of great slow orogenic movement, probably that in which occurred by far the maximum uplift of the Alps. The corrugation of all pre-existing rocks was enormous, though this folding was, of course, much more intense at the centre of crumpling than at the edges. It is not unlikely that it was during this time that the main axis of land progressed from its old position eastward approximately to the present position of the Island divide.

During or perhaps just following Lower Cretaceous times came the intrusion of basic dykes, and to a very slight degree the effusion of basic volcanics. The Alps at this time rose to magnificent heights, and the glaciation which later reached such immense proportions possibly commenced.

In Miocene time followed a long period of slow and very gradual depression, during which quite 1,000 ft. of clays and sandstones were deposited on the north-western shore. The deposition of sandstones was chiefly towards the south-west of the Hokitika Sheet. The clays in general which made up this formation—the Blue Bottom—have a strong resemblance to a compacted deposit of glacial rock-flour, and it is certain from the evidence of striated cobbles that at least the upper part of this thick deposit derived much of its material from glacial corrasion in the eastern mountains.

Orogenic movements were comparatively slight in Miocene times but were by no means wanting, and in many places along the base of the mountains we find abundant evidence of warping. The Miocene subsidence closed with the deposition of thick beds of conglomerates—the Humphrey's Gully beds—300 ft. or more in thickness.

Then commenced a period of secular elevation which has probably continued with probable minor cessations until the present time, and possibly with this elevation ensued changed meteorological conditions which increased the precipitation of snow and caused an advance in the glaciers.

In this connection it is interesting to note that Professor Albrecht Penck, the great Austrian glaciologist, considers that the depression of the snow-line in New Zealand is due to the presence of a mountain chain stretching across the direction of the prevailing winds.* Primarily the ice streams started as piedmont glaciers, but gradually grew, their ice increasing in thickness until the glaciers united over the intervening spurs. Slowly the ice sheet advanced, until it had covered practically the whole of Westland, and extended far down into Canterbury as well. Above this huge ice pall the highest mountains stood out as lonely nunataks.

The exact time of the maximum advance of the glaciers is considered by Captain Hutton to have been in Upper Pliocene time, but other authorities, including Professor James Park, consider it was in early Pleistocene time. One thing is certain, and that is that the glaciation started in Miocene time and is still continuing. While the glaciers were advancing, and until they had reached the maximum stage, they were destructive rather than constructive; but with the retreat started the major deposition of the morainic *débris* (morainic gravels), which is such an important surface constituent of the area within the influence of the alpine zone. The immense amount of this *débris* testifies to the enormous denudation of the mountains which has taken place, and especially of their softer rock constituents.

While this morainic material was being laid down the rivers which flowed from beneath the ice were depositing fluviatile material on the low-lying lands at the frontal face, and at the same time stratified gravels were being laid down close to the sea-margin. The river material close to the ice was in the main coarse and but slightly assorted, and is hence more correctly spoken of as fluvio-glacial, and there is probably every gradation from morainic to fluvio-glacial, fluviatile, fluvio-marine, and glacio-marine. These points will be elaborated farther on in this report. In general it may be said that part of the marine and fluviatile sedimentation was contemporaneous with the morainic deposition.

The retreat of the glaciers was, of course, not a rapid one, and there were undoubted minor advances. Some of these minor advances deposited ice-laid material on top of both fluviatile and marine material laid down when the glaciers had temporarily retreated. Gradually, however, but spasmodically the ice left the lowlands. This slow retreat may have been due to the actual diminution in the height of the mountains by ice-corrasion, with a corresponding decrease in the size of the *névé* which fed the huge ice streams, or it may have been caused by a change of climatic conditions. At present within the area covered by this bulletin the ice streams have regressed to the tops of the highest river-courses, and remain simply as tiny piedmont glaciers or as small ice blocks perched on the sides of the loftiest hills. Very little morainic material is being deposited, but fluviatile deposition along the various watercourses and marine sedimentation are still progressing.

### GENERAL ACCOUNT OF THE STRUCTURE OF THE SEVERAL FORMATIONS.

Though no unconformity is visible in the Arahura series, it is very probable that these rocks represent the deposits of several periods. Apparently the oldest rocks are metamorphic schists of various kinds, while the youngest rocks or the highest in the series are argillites and grauwackes. The rocks are folded into a great synclinorium with major folds striking about north 30° west. The dips are both to the south-east and to the north-west. The mountains are in the main synclinal in structure, while the principal valleys are incised along the crest of the anticlines.

The Kanieri series are, on the whole, much less regular in structure than the Arahura series. The rocks of the former are in general less metamorphic than those of the latter.

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* "Climatic Features of the Pleistocene Age": *Geographical Journal*, February, 1906.

The Tuhua granites are but slightly gneissoid. The general trend of the main mass is parallel to the structure of the Arahura series.

The Pounamu formation is irruptive into the rocks of the Arahura series, but for the main part follows the strike of these rocks.

The basic irruptive dykes and volcanics are limited to a very few localities. The dykes have no general trends, but run in several directions within a short distance.

The rocks of the Koiterangi series are in part tremendously crumpled. The area at Gentle Annie is a much broken basin, while that at Koiterangi is apparently a faulted block, with rocks dipping mainly towards the east.

The Blue Bottom in the main lies horizontally, and is remarkably uniform in general lithological character for long distances.

The Humphrey's Gully beds are only rarely tilted. The principal constituent of these gravels is grauwacke *débris*.

The morainic beds are quite structureless, excepting where narrow layers of material deposited by an englacial or subglacial streams occur.

The fluviatile and marine beds, following the maximum advance of the glaciers and still forming, lie in general horizontally, though with a gradual dip seaward.

# CHAPTER IV.

## THE PHYSICAL GEOGRAPHY OF WESTLAND.

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### General Physiographic Features.

The District of Westland presents many features of great geographical interest and a wonderful variety of physiographic forms within so limited an area. The most splendid of these features appear panoramically before the gaze of the observer looking eastward from the shore of the Tasman Sea on a fine day. Beautifully outlined against the sky is the serrate profile of the Southern Alps, with many splendid peaks rising to lofty and varying heights. Nearer at hand lies a sea of lower crests with rugged rocky summits, which in summer are only rarely clad in snow. One of the most remarkable features of these lower peaks is the generally uniform level to which they rise. Westward from this wild, deeply-cut country rounded wooded outliers surmount the eastern edge of a low plain which gradually slopes to the level of the Tasman Sea.

From the summit of any of the low outlying granite hills—Mount Turiwhate, Island Hill, or Mount Tuhua—the uniform elevation of the peaks to the eastward, west of the main alpine ridge, is very striking, and is much more apparent than when viewed from the sea-shore. These peaks rise, as a rule, to between 4,000 ft. and 5,000 ft., and only very seldom to greater altitude. The uniform elevation seems to indicate a former base level of erosion for this part of the country, which may be spoken of as an elevated plain of erosion or peneplain. The few peaks which rise above the general level of this peneplain are residuals left after the erosion of the surrounding land, and may be considered monadnocks. The low plain which extends from the peneplain to the sea is a relatively modern feature—a new coastal plain. The rounded hills at its eastern edge are outliers from the peneplain.

The main physiographic features of Westland, then, are the alpine chain, an elevated peneplain (here spoken of as the Wainihinihi peneplain), and the coastal plain. On the various large rivers which flow in general at right angles to the alpine chain, the edge of the Wainihinihi peneplain is marked topographically by a deep gorge usually with falls or heavy rapids. The artificial demarcation which joins these falls as represented on the main rivers is spoken of as the fall-line.

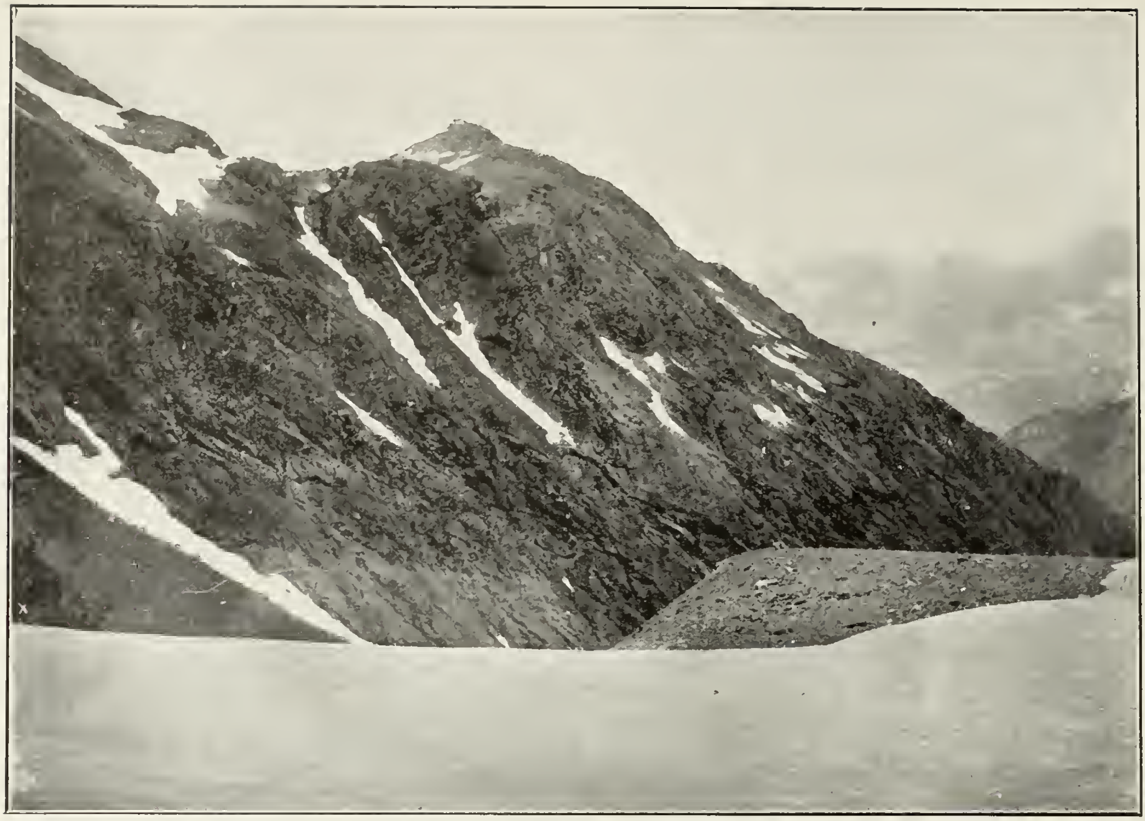
The principal drainage channels of the area covered by the Hokitika Sheet are the Teremakau, Arahura, and Hokitika Rivers, and to a much lesser extent the Totara River. All these flow to the Tasman Sea and are purely West Coast streams, while the small triangular section in the Waimakariri Quadrangle of the Canterbury District, near Browning's Pass, which is included in the area under review, is drained by the Wilberforce, a tributary of the Rakaia, flowing to the east coast.

### The Alpine Chain.

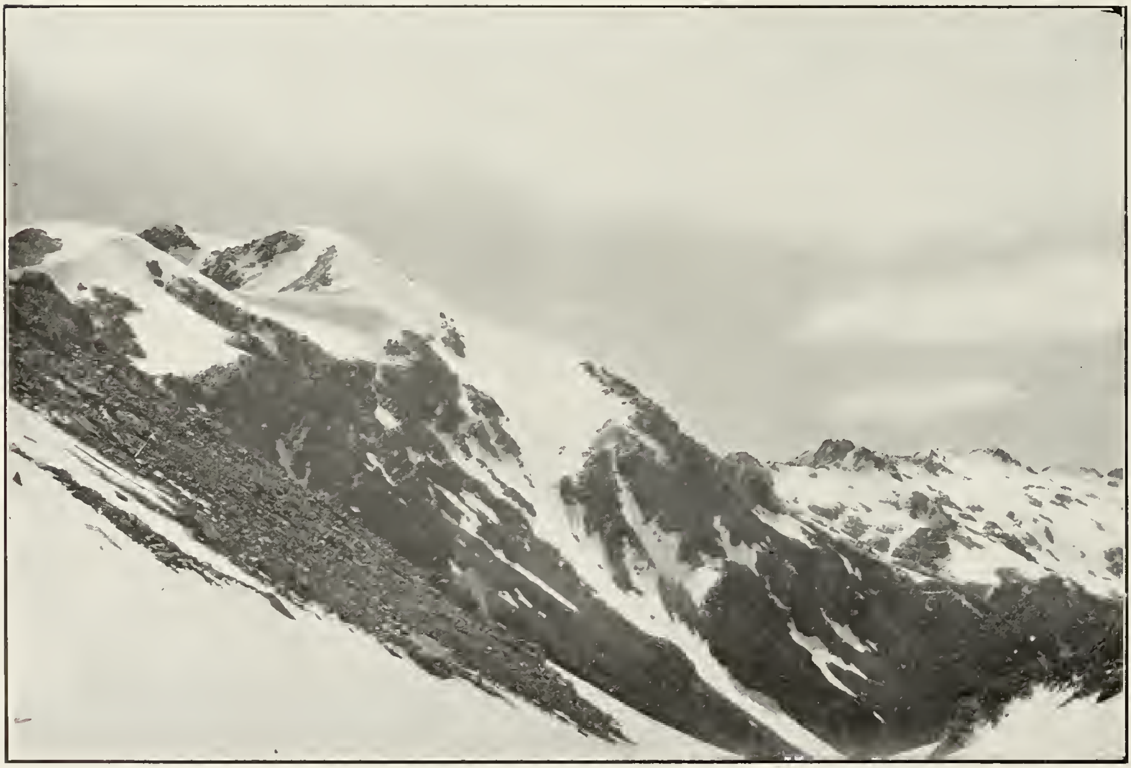
The loftiest peaks of the alpine chain lie east of the main island divide on ridges branching from the main chain. Very roughly, the maximum width of the alpine chain may be set at about fifteen miles, but, of course, there is no decided demarcation between this feature and the

High peak on Rosamond Ridge.

Mount Rosamond and Whitehorn's Pass.



Mount Marion, viewed from summit of Pope's Pass.



Mount Axis and the Campbell Range, from Pope's Pass.

mountainous Wainihinihi peneplain on the west, or between it and the mountainous country on the east side. Despite the relatively recent occurrence of the maximum uplift of the Alps, they are old mountains, at least submaturely dissected. They owe their majestic appearance not so much to the great altitude of their uplift as to the magnificence of their dissection. The maze of rugged ridges and spurs, divided by deep valleys and ravines, gives a very intricate topography, and presents but small indication of the original form. In general, however, the Alps are a folded mountain chain with the chief axis nearly parallel to the principal folds. The subsidiary ranges which radiate from the main ridge have their greatest length generally transverse to the rock-structure, and owe their configuration to the influence of the principal drainage channels. The decay of the alpine chain owing to the lack of hard resistant rocks has been very rapid in the past, as evidenced by the tremendous mass of *débris* which makes up the broad fertile Canterbury plains on the east and the narrow Westland coastal plain on the west. The initial weakness of this strata, coupled with the enormous shattering which the rocks have undergone during the long continued orogenic movements, may have accounted for the very rapid decay of the Southern Alps, the rate being still further accelerated by the various meteorological conditions to which they have been subjected. Recently, perhaps, denudation has been somewhat retarded by the thick covering of the products of decay. Still, however, the denudation proceeds rapidly, as is well evidenced by the numerous talus slides, the gravel stream fans, the frequent absence of rock *in situ* on the mountain summits, and the discolouration of the mountain streams with every shower.

The general direction of the main alpine chain is about north-east, though there are variations from this direction. From Browning's Pass, at the head of the Arahura and Wilberforce Rivers, the chain runs northward in a direction of north 68° east, and southward in a direction of south 38° west. In the main the alpine chain is synclinal in structure, as also are nearly all of the principal mountain peaks in the subsidiary ranges. The highest peaks consist generally of grauwacke or sandstone rather than argillite, though this latter constituent may also be very important.

The alpine divide from the Cascade Saddle, at the head of the Waimakariri, to just beyond Mount Park, at the head of the Gibson, lies within the area covered by the Hokitika Sheet. It is a region of broken rugged crests, most difficult of access. The loftiest peaks of the divide are: Mount Rosamond, 7,197 ft.; Mount Pope, 5,618 ft.; Mount Harman, 6,170 ft.; the Twin Peaks—Mount Augusta, 6,197 ft., and Mount Emily, 6,289 ft.; Mount Walter, 6,350 ft.; Mount Learmont, 6,697 ft.; Mount Keddel, 6,465 ft.; Mount Fitzgerald, 6,568 ft.; Mount Ambrose, 6,598 ft.; Mount Eliot, 6,740 ft.; and Mount Treadwell, 6,919 ft.

The sculpturing of the chain is exquisite, the upper slopes often precipitous, being broken, rocky, and practically bereft of vegetation, while the summits are everywhere patched with snow. A fine buttress of grauwacke, known as Rosamond Ridge, runs down on the Canterbury side between Cronin Creek and the head of the Wilberforce. Along this ridge are some of the most massive and splendid peaks in the area, which include Mount Marian, 6,816 ft., and Pampero's Knob, 5,963 ft. Between the Gifford and Hall Creeks descending from Mount Walter is Reese's Ridge, showing Reese's Peak and many other lofty crests. The ridge between the Gifford and the Griffiths, known as the Cabot Ridge, exhibits several splendid snow-covered peaks, among which may be mentioned Mount O'Brien, Mount Camsell, Mount Scott, and Mount Cabot. At the head of the Eliot Ridge, between the Griffiths and the Gibson, both tributaries of the Stewart River, which flows into the Wilberforce, is one of the highest peaks in the area under discussion—Mount Eliot, which rises as a stately snow-clad cone, with pronounced local relief, above the surrounding country. Lower down the ridge are several other peaks of considerable altitude.

On the Westland side of the Alps the principal ridges jutting out from the main divide within the Hokitika area are the Browning Range, the Campbell Range, and Hunt's Range. All of these are the eastward extension of the Wainihinihi peneplain, into which they gradually pass to the westward and northward. On the Browning Range are situated the prominent peaks of Mount Lathrop, Mount Macdonald, and Mount Browning. Mount Axis is the highest crest on the Campbell Range, and was snow-covered throughout the past summer (1906). The crest of Hunt's Range presents no very pronounced summits, but gradually slopes northward from Mount Rosamond, which marks its southern extremity, to the point where it is cut off by Hunt's Creek.

### THE WAINIHINIHI PENEPLAIN.

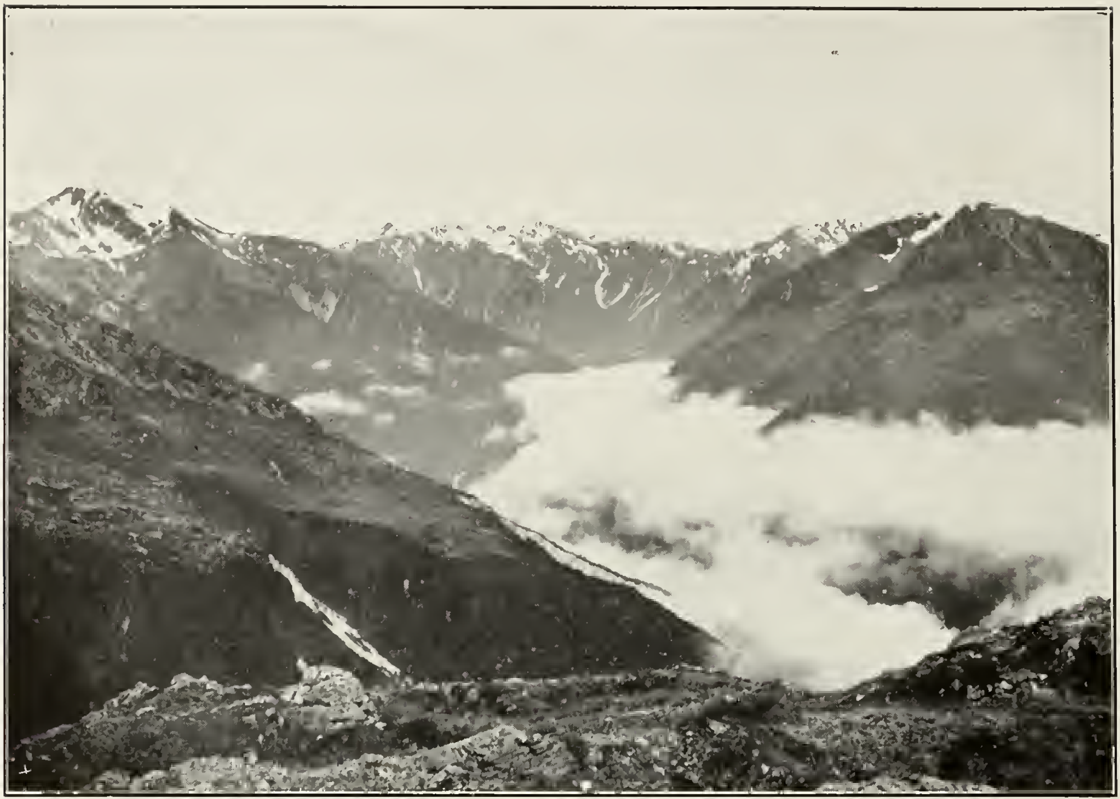
The Wainihinihi peneplain extends westward and north-westward from the edge of the main alpine chain to the eastern limit of the coastal plain. Its eastern boundary is distinctly an arbitrary one, as, of course, the peneplain and the alpine chain grade imperceptibly into each other. Its western border may be more precisely delineated, and practically corresponds with the western limit of the ancient schistose rocks of the Arahura series, which runs from the north-eastern boundary of the Turiwhate Survey District by the Rough Wainihinihi, the Wainihinihi, and the southern end of Kanieri Lake. Portions of this wide stretch of broken mountainous country have distinctive names where separated abruptly by the principal stream channels—the Newton Range stretching from Mount Newton to Mount Brown, between the Styx and Arahura Rivers; the McArthur Range between Olderog's Creek, the Arahura, and the headwaters of the two Wainihinihi Creeks; the Griffin Range between Griffin Creek and the Rough Wainihinihi; Scotty's Range between Scotty's Creek and the Taipo; while the main central part is known as the Tera Tama Range. At the close of summer practically all of these ranges are quite free from snow, and alpine or subalpine vegetation may be found all over the Wainihinihi peneplain.

In general the configuration of the Wainihinihi peneplain is wonderfully interrupted and diversified. The ridges connecting the various higher peaks are in many places worn to sharp razorbacks, while the divides between the various deeply incised creeks are not infrequently cut back almost to the narrowness of a knife-edge. Of all this intricate and apparently irregular topography there is one physiographical feature which is remarkably uniform, and that is, as mentioned above, the general equality in the altitudes of the various summits, and it is this feature which indicates the peneplain.

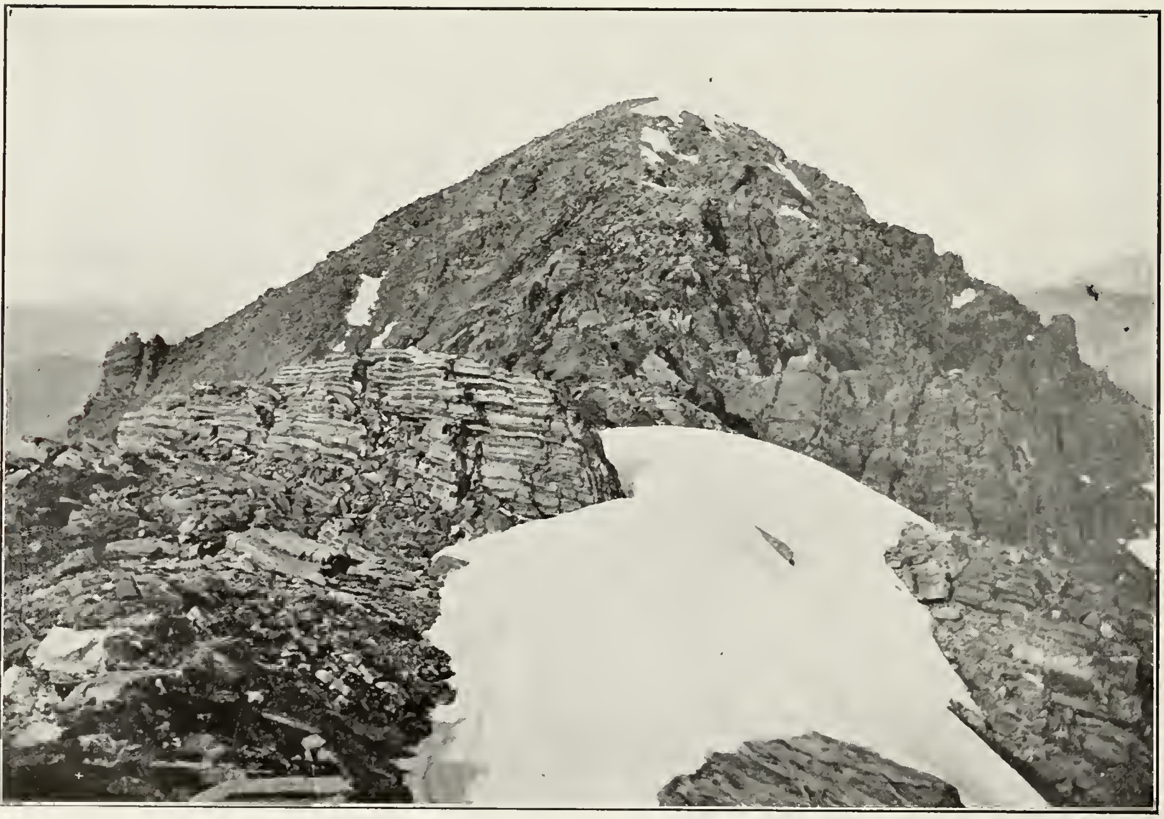
The height of this elevated peneplain is between 4,000 ft. and 5,000 ft. Not many peaks rise above the last-named height, and these few may be classed as decided monadnocks—outliers from the alpine chain which represent a still earlier cycle of erosion. The most prominent of these monadnocks are Mount Tera Tama, Mount Walcott, and Mount Newton. Mount Tera Tama is the highest and quite the most commanding mountain of the Wainihinihi peneplain; its crest shows two peaks divided by a narrow, broken ridge, strewn with large angular fragments from the underlying rocks. The highest and most eastern peak stands some 6,084 ft. above sea-level, and there is always some hardened glacier-like snow on the northern side of this apex. In places on the slopes of the principal peaks there are stretches of fairly flat country, covered with a healthy growth of mountain grass, particularly on Griffin Range and around the base of Edelweiss Knob.

Campbell Range, which may be partly considered within this physiographic province, stretches rough and broken to Mount Axis, already mentioned. The McArthur Range is separated from Griffin Range by a particularly steep and impassable razorback, while the McArthur Range itself shows profiles particularly bold and precipitous.

The age of the Wainihinihi peneplain may be considered as not earlier than the period of maximum orogenic movement or as subsequent to the deposition of the Koiterangi series. It may be the northward continuation of the peneplain produced by differential elevation mentioned as



THE VALLEY OF THE UPPER ARAHURA, VIEWED FROM MOUNT TERA TAMA.



THE SUMMIT OF MOUNT TERA TAMA.

occurring in south-western New Zealand.* The outliers from the Wainihinihi peneplain—Koiterangi, Mount Tuhua, Mount Graham, Conical Hill, Island Hill, Mount Turiwhate, and the Hohonu Range—represent features which were islands in the advancing sea during the close of the Miocene subsidence, but were at a more remote period a portion of the old land to the east.

Mount Tuhua is a razorbacked ridge stretching in a general direction of south 22° east, and exhibiting three prominent peaks, the central being the highest, conical in shape, and separated from the other two by low valleys in the razorback. To the northward the mountain slopes gradually to the surface of the coastal plain, while to the southward it descends to a broken country, stretching towards Mount Brown. Eastward it falls precipitously to the Arahura Valley, while westward it slopes in several spurs to the shore of Kanieri Lake. The highest peak rises to a height of 3,688 ft., and its summit is practically bereft of vegetation.

Koiterangi is a typical example of an outlier; it is a rounded ridge with three pronounced peaks, the highest of which is 1,841 ft. above sea-level. Mount Koiterangi is well wooded to the summit.

The summit of Mount Turiwhate consists of several broken sharp serrate peaks, separated by grassy saddles, which are in places flat-topped. Sometimes the highest pinnacles descend abruptly to flat shelves, situated some hundreds of feet below the main ridge, while again the precipices are relieved by talus slopes. These flat shelves are of the same nature as the grassy saddles which divide the main ridge, and both occasionally are surmounted by irregular, bizarre, granitic remnants which resemble the curious forms known as "Hoodoo's Columns."† In places the precipices which flank the ridge are beautifully smoothed by ancient ice-action, and on the slopes rounded knobs appear which are typical *roches moutonnées*. In places the precipices descend to deeply gorged valleys which drain the mountain-sides.

The Hohonu Range topographically resembles Mount Turiwhate, but is even more broken, rugged, and precipitous. Its summit shows a number of prominent peaks separated by grassy flats, flanked in many places by steep precipitous faces most difficult of access.

## COASTAL PLAIN.

The coastal plain of Westland as it is seen to-day is a decidedly complex physical feature. The modern plain is superimposed upon an earlier plain composed of the clays of the "Blue Bottom" and of the Humphrey's Gully gravels, while outliers from this earlier plain stand in relief above the modern feature. The most prominent of the remnants from the older plain are the Humphrey's Gully Range and Fox's Range. Another complicating feature is the tremendous amount of glacial *débris* which has been irregularly deposited, and forms much of the surface material of the modern coastal plain. Still further, the modern coastal plain itself is being deeply incised by the various streams which traverse it, forming numerous fluviatile plains or flood plains, the largest of which is the Kokatahi plain. Thus a distinct third major cycle is coming into evidence on the coastal plain, in addition to the many minor cycles shown by the numerous terraces along the various rivers.

The coastal plain of Westland may be said to have been inaugurated by the Post-Miocene elevation. Though its surface has been tremendously altered by various erosive agencies, chiefly glacial and fluviatile, its basement has probably remained much the same as at the time of its uplift. The eastern boundaries of the coastal plain correspond with the western border of the old land. Its greatest width may be set at about fifteen miles, and the maximum elevation of its inner edge is probably little over 600 ft., although the outliers—Humphrey's Gully Range and Fox's Range—rise to greater altitudes. The Humphrey's Gully Range is a long hogsback ridge of remarkably even crest-line, which rises to a height of 1,250 ft. Fox's Range, which is of much greater lateral extent than the Humphrey's Gully Range, rises with an even crest-line practically to the same altitude as the latter.

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* "The Ice-flood Hypothesis of the New Zealand Sound-basins," by E. C. Andrews, "Journal of Geology," Vol. xiv. No. 1, 1906.

† Common in the Black Hills of Southern Dakota.

## The Rivers of the Area.

The main drainage channels of the area considered in this report are the (1) Teremakau–Taipo River system, (2) the Arahura River system, (3) the Hokitika River system, and (4) the Upper Wilberforce River system. The Arahura watershed covers the greatest portion of the area, and exercises much the greatest influence. The sculpturing of all the rivers is that typical of all intensely glaciated countries, and here an interesting contrast may be drawn between the rivers of the northern part of New Zealand and the same features in Westland. In general the most characteristic feature of the rivers in the former part of the country is the well-ordered character of their drainage; the main valleys are well matured, the side valleys enter with practically the same gradient as the main channels, and there is an absence of waterfalls and rapids, save in the headwaters of the smaller streams, where, in newer and mountainous country, they may be quite common, or when profoundly influenced by seismic or volcanic action. An absence of long straight stretches of river valley and a frequency of serpentine valleys characterized by overlapping spurs jutting from the opposing sides are representative features. In the mountain streams narrow, tortuous, gorge-like channels are also conspicuous.

Contrasted with these, the prevailing physical features of Westland stand in marked variance, and exhibit direct evidence of glacial action. The principal river valleys are in general broad and U-shaped, and the spurs from the main valley walls are frequently abruptly truncated or absent altogether. Rapids, cascades, and falls may occur anywhere along the course of the rivers. Lakes are common features not only in the highlands but in the lowlands, and mountain tarns are very common in high altitudes. The tributary streams rarely enter the main stream at grade, but generally either leap precipitously in steep falls from perched valleys, or enter in a series of rapids and chutes in marked disagreement in inclination with the main stream. In the headwaters of the various main streams contracted waterways are lacking, but instead there is usually a broad, deep, and frequently inaccessible cirque, in which pretentious feature the tiny streamlet is almost lost.

The minor streams show the same features as those of major importance. One sees the relatively broad U-shaped upper portion frequently filled with talus from the adjoining sides, and always having its inception in a steep-walled cirque. From the cirque the smaller tributary streams usually flow for some distance with a fairly even descent, though with frequent falls: much the greatest descent, however, is generally close to its junction with the major stream, the steepness of this fall depending on the character of the country, while its position with reference to the main river drainage varies with the amount of back incision from the original position which the stream has been able to accomplish since the departure of the glaciers formerly filling the main and tributary streams. The amount of cutting undergone varies, of course, with the character of the rocks through which the stream flows. Towards the headwaters of the main stream the tributary streams enter very steeply, either descending over talus slopes or dropping precipitously in a series of falls. Even in the tiny rivulets entering tributary streams one not infrequently sees this extraordinary discordance in grade at their junction, the smaller stream entering the larger in a hanging valley.

The Flood Plain of Kawhaka Creek, near the old Kawhaka Inn.

Outlying Mountains on the Coastal Plain, seen from the base of Mount Koiterangi.

*Geological Bulletin.*]

The main drainage channels, as a rule, run either directly across the strike of the country rocks or otherwise along them. When parallel to the stratification they not infrequently flow along the much denuded crest of an anticline. The minor streams traverse the strata with no definite angle. Narrow gorges, which probably often follow planes of structural faults, are modern features as a rule, and generally occur in hard compact strata, where the river valley has been incised by purely fluviatile cutting since glacial times, while open river flats exhibit river-action subsequent to the glaciers in soft strata, often in the *débris* deposited by the ice.

Only a very small portion of the main Teremakau Valley is within the area covered by the Hokitika Sheet, though its tributaries, the Taipo River, Griffin Creek, and the Rough Wainihinihi, all important streams entering from the south, are within the area. Many lesser streams join the main river on the southern bank, and on the northern side many small creeks flow off the Hohonu Range into the river. The Teremakau River itself follows an immense structural fault at right angles to the trend of the main alpine folds. Its valley is broad and majestic, and the grassy river flats which alternate on either side afford good sheep-runs. Where the stream abuts against the side of the Hohonu Range or Mount Turiwhate, hanging valleys enter the main stream directly. Conspicuous among the latter is Smart Creek, which has a beautiful fall a few chains above its mouth. The Teremakau has apparently seen many changes in its course. In the time of maximum glaciation a portion of the Teremakau Glacier flowed between Turiwhate and Island Hill, while possibly another part flowed between the McArthur Range and Island Hill, joining the main Arahura Glacier. Probably even more recently than glacial times the river flowed across the Lake Poerua Flat into Lake Brunner, and thence its waters reached the Grey River through the Arnold. The Orangepuku, which at one point flows parallel to the Teremakau and within a quarter of a mile from that stream, probably represents the shrunken remnant of this former river, which has been deflected to its present course. To-day a very shallow cutting would turn the Teremakau to the Grey. The water of large springs which bubble from the boulder banks along the Orangepuku evidently comes from the Teremakau, as the amount of water which they eject depends directly on the quantity of water in the Teremakau, and hence some of the water of the river still finds its way along the Orangepuku. The modern Teremakau may thus in a way be considered a subsequent stream. The lower part of the Rough Wainihinihi, running contrary to the direction formerly pursued by the Teremakau Glacier, which formerly flowed towards the Arahura, is an obsequent stream. Griffin Creek and Rough Wainihinihi Creek drain the rugged interior of the Wainihinihi peneplain. Both are gorged at the point where they leave the mountains, and enter the Teremakau Valley discordantly. Their upper waters are fairly easily reached from the top of Griffin Range.

The Taipo, which joins the Teremakau practically at grade, was probably in glacial times a tributary of almost equal force with the main stream. It is formed by the union of two branches, the southern and most powerful rising in a magnificent cirque at the base of Pope's Pass. The Taipo is an almost perfect example of a stream formed by glacial influence on a pre-existing stream-channel incised along the crest of an anticline, and exhibits splendidly all the characteristic features. Near its head the U-shaped valley is much choked with talus from lofty hills on either side. A succession of narrow gorges broken by longer stretches of grassy river-bottom, in which the stream flows in many and ever-changing channels, characterize the river valley through much of its course below the forks. Cascades are common in the upper part of the river, though not exactly at the headwaters, and rapids occur throughout its course.

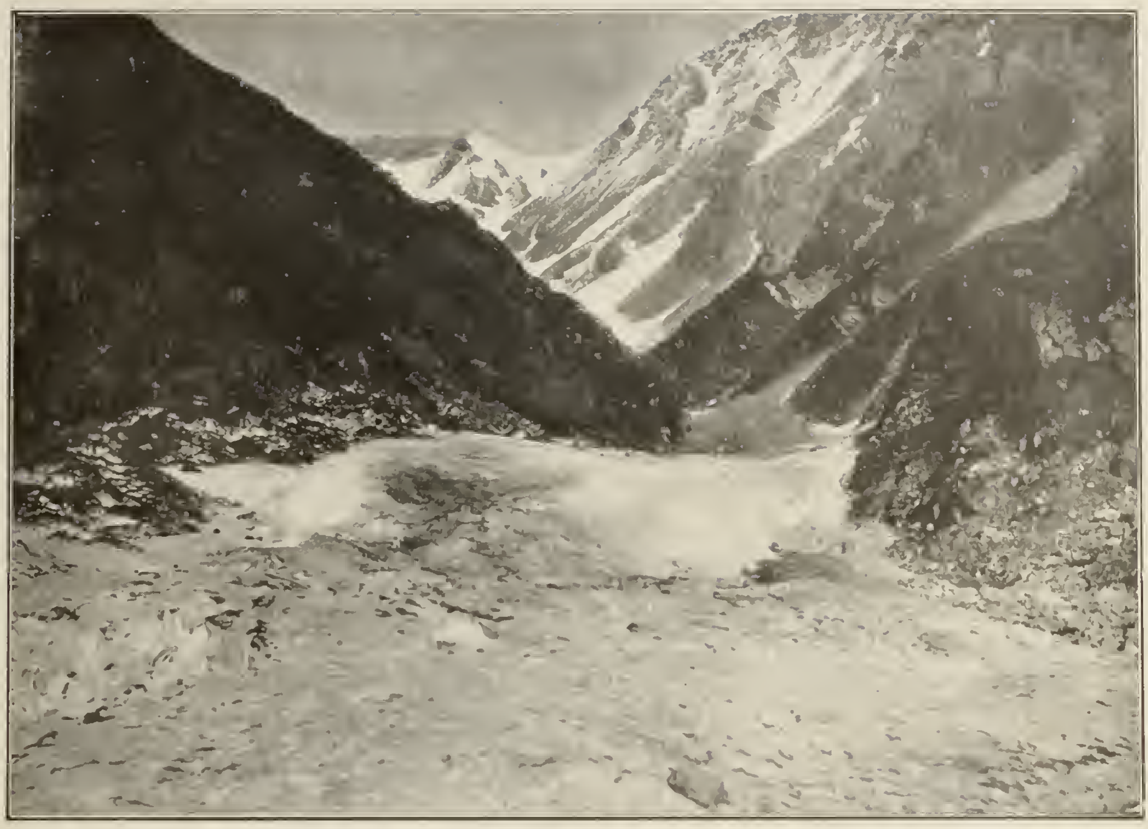
The Taipo has many tributaries. The most important on the eastern side is Hunt's Creek, a stream which in glacial times flowed directly to the Otira River and Teremakau, as evidenced by a broad saddle which still connects it with the former river through Kelly's Creek. Succeeding glacial times Hunt's Creek was captured by the Taipo, and is hence a subsequent stream.

Entering the Taipo from the west are a number of large streams dropping from the slopes of the Tera Tama Range. All are characteristic glacial streams, the principal ones being Rocky Creek, Scotty's Creek, Dunn's Creek, Hura Creek, and Dexter Creek. Rocky Creek has a very steep descent in its upper part, though a somewhat more gradual inclination near the main river. This stream was formerly the path of a large glacier, as the broad valley still visible in places testifies. Scotty's Creek has in general a gradual though much broken descent to the main river, while Dunn's Creek is a most difficult creek to travel, owing to the numerous boulders which it contains and because of the high broken waterfalls about a mile and a quarter above its mouth. It rises in a cirque at the foot of Mount Tera Tama, and for some miles follows a broad U-shaped valley. Hura Creek is of comparatively easy grade to its headwaters; its most southern branch rises in a small cirque at the base of a low saddle which separates the Campbell Range from the Tera Tama Range, while the more northern stream flows from the base of a long talus slide below Edelweiss Knob. Just below the junction of its two principal branches Hanging Creek enters in a magnificent fall from the rugged mountain-sides. Hura Creek enters the Taipo in a boulder-fan. Dexter's Creek flows steeply from the Campbell Range over bouldery talus slopes, and enters the main stream in a boulder-fan. Dry Creek, which joins the Taipo a short distance below Dexter Creek, also enters in a boulder-fan; a pass at its headwaters leads into Hunt's Creek.

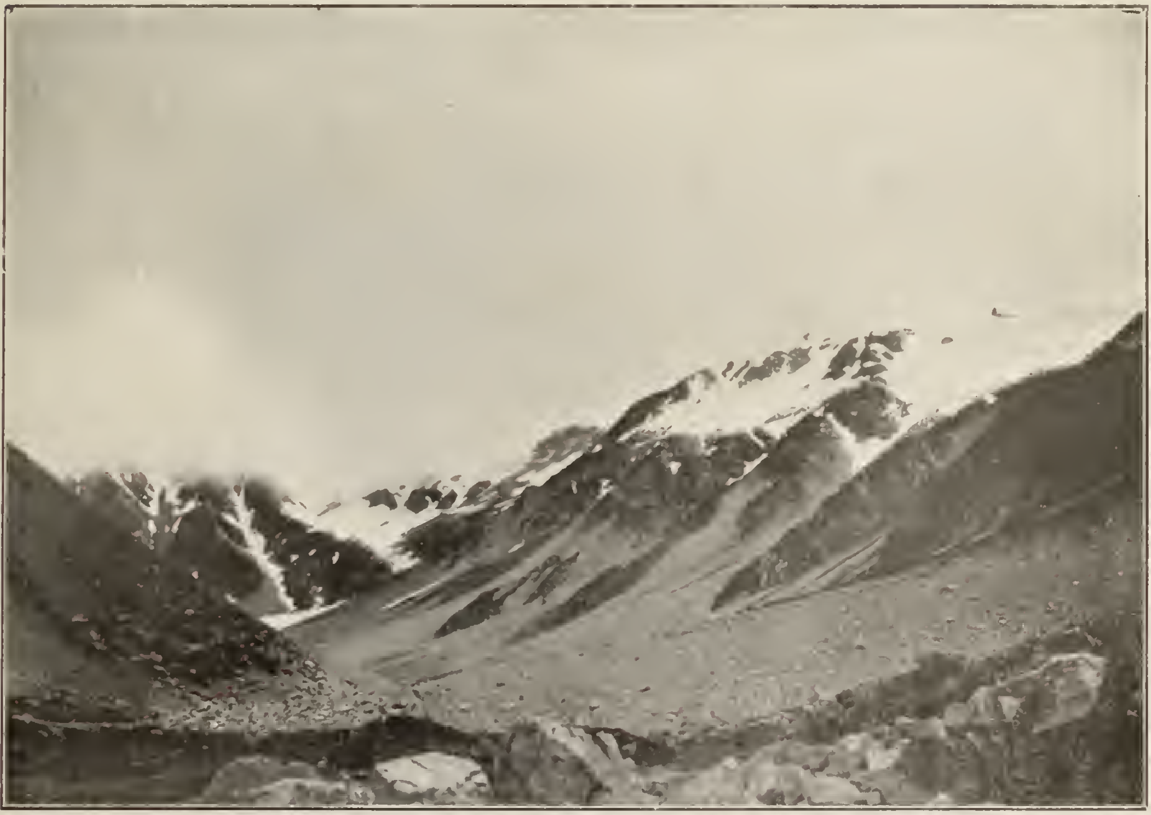
The Arahura in part follows the strike of the strata and in part flows across it. It rises on the island divide in Lake Browning, 4,510 ft. above the sea. Thence it has an abrupt descent in a northerly direction of nearly 1,400 ft. in a series of falls to a broad cirque. Leaving the cirque it turns westerly to the junction of the Harman, where it assumes the direction of that stream, about north 25° east, to the Third gorge. At the Third gorge another sharp bend takes place, turning the river to the westward. Just below the Second gorge the river again bends, and flows in a generally north-westerly course to the sea. The Arahura River is a typical glacial stream, showing the usual diversification of narrow gorges and river flats, depending on the character of the strata and the amount of dissection since glacial times. The curious irregularity of its course has apparently a pre-glacial signification.

The principal streams entering the Arahura from the north are Kawhaka, Wainihinihi, Olderog's, Newton's, and McQuilkin's Creeks; while those joining from the south include Hau Hau, Caledonian, Mount Brown, Clarke's, and Harman Creeks. The lower parts of both Kawhaka Creek and Wainihinihi Creek represent the beheaded drainage of former distributaries of the principal Teremakau Glacier. The various streams flowing from the mountains on either side of the Arahura are tumultuous mountain torrents, rising in high mountain cirques or corries, and rendered difficult of descent or ascent by innumerable waterfalls and rapids, and by immense boulders which fill the stream-beds. Hanging valleys directly entering the Arahura are common, especially towards the headwaters of the river. The entrance of Newton's Creek is a typical example of this feature, the abrupt fall from the perched valley being not less than 200 ft. After entering the coastal plain the Arahura Valley rapidly widens, the river being bordered by broad flood plains from which successive terraces rise and represent its former level.

Most of the Hokitika River basin is outside of the area at present considered. Its main tributary—the Kokatahi—has two of its three branches—the Styx and Kokatahi proper—rising within the Hokitika Sheet and draining the mountainous hinterland; while the third tributary—the Toaroha—is outside the area. The Hokitika is a typical engrafted river, and its four principal components—the Hokitika proper and the three branches of the Hokitika—leave the old land separately, uniting only on the coastal plain, before the uplift of which they represented four distinct river systems. The Kokatahi Plain, with its fertile fields, flax marshes and swamps, is the flood plain of these various rivers, which traverse it swiftly, though with no rapids of any magni-



PART OF GRAVE CREEK GLACIER.



THE VALLEY OF THE UPPER TAIPO RIVER, WITH MOUNT AXIS ON THE RIGHT.

tude. Terraces along their courses show the dissection of the coastal plain by these rivers since its elevation.

The Styx, which is a beautifully straight, clear-watered river, rises on the Styx Saddle. At its headwaters waterfalls are common. Its modern valley is in its lower part, incised beneath the ancient glacial floor. Formerly this river valley carried a huge ice stream, a distributary of the Arahura Glacier. Another creek of much smaller proportions than the Styx rises on Styx Saddle, and flows to the Arahura against the drainage formerly followed by the Styx portion of the Arahura Glacier, thus exhibiting an obsequent stream. The two branches of the Kokatahi proper, which rise within the Hokitika area, have typical ice-formed valleys, and commence in very small existing glaciers. Their upper courses are rough and broken, but by no means inaccessible. Kanieri Creek, draining the lake of the same name, is a modern post-glacial feature, though in part along ancient drainage. Its many tributaries—Butcher's Creek, Coal Creek, and Bluebottle Creek from the south, and Kennedy's Creek and McKay's Creek from the north—drain the Gentle Annie and Conical Hill on the one hand, and Humphrey's Gully Range on the other.

On the coastal plain the drainage in general flows directly down the gentle dip of the strata, and may be spoken of as consequent drainage. There are a great many small streams traversing the coastal plain. Very few of them, however, enter the sea independently, but, instead, are deflected either north or south to one or other of the prominent drainage channels, which are sufficiently powerful to combat the strong sweep of the northerly current along the coast, and find entrance into the ocean.

The Totara Lagoon, which runs for many miles parallel to the coast, connects many consequent streams. Its outlet into the sea frequently changes. A strong westerly gale will block the mouth with gravel; then the level of the lagoon will rise until the water is strong enough to again break an entrance into the sea at the weakest point. Of course, at all times much of the water of the Totara Lagoon reaches the sea beneath the gravel of the sea-beach, and when the inlet is closed practically all the water leaves it in this way. The outlet of Lake Mahinapua is by the creek of the same name. Though the embouchure of the lake is within one mile and a half of the sea-beach, it has to flow quite three times that distance almost parallel with the coast before it joins the Hokitika River. Possibly in former times the main part of the Hokitika flowed to the sea by the Mahinapua, and to this day the flood waters of the Hokitika River reach Lake Mahinapua through Grove Swamp and the Remarkable Gap.

One of the curious features of the West Coast rivers is the abruptness with which they become large streams a short distance from their headwaters without many apparent entering streamlets. The reason for this change is probably to be found in the presence of innumerable small springs which join the main channel beneath the gravel. The large streams flowing into Lake Kanieri, such as Kent Creek, Hooker Creek, and Geologist Creek, all enter in huge fans, which are rapidly filling up this deep basin. Scarcely any water is visible at their mouths, as it nearly all reaches the lake beneath the gravel.

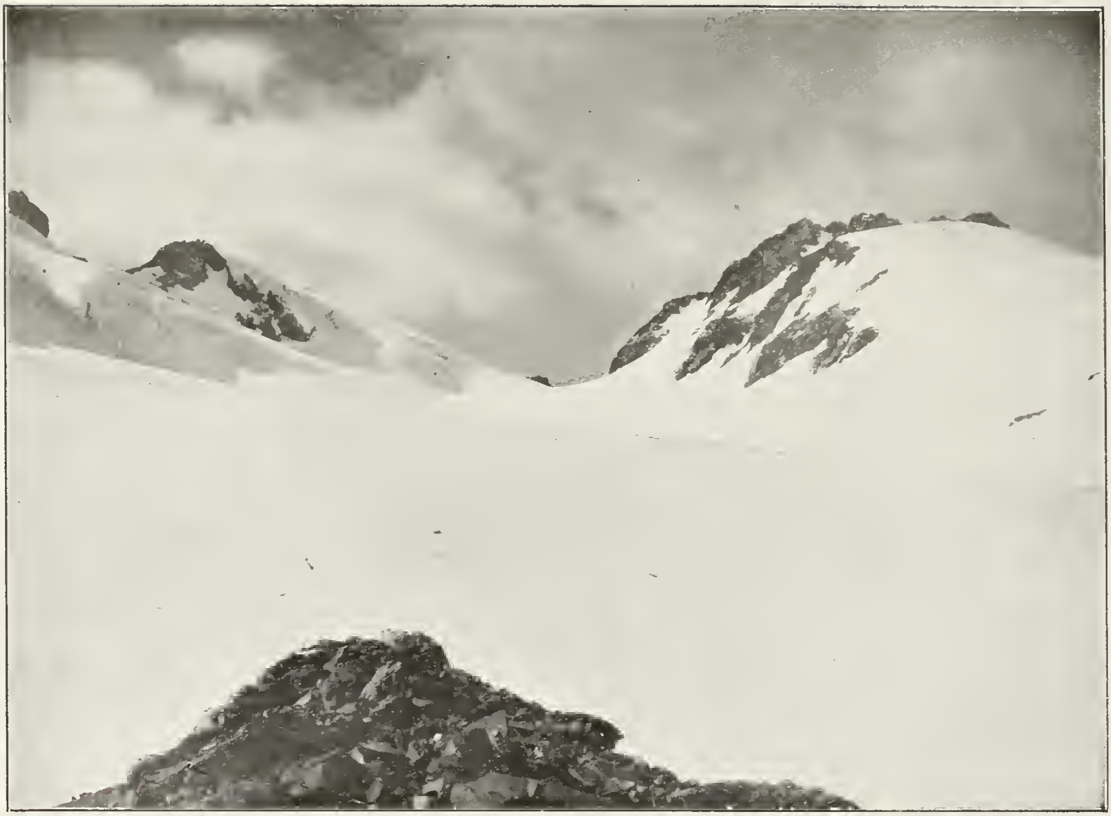
The Upper Wilberforce River is another typical glacial stream with the chief part of its valley lying on the eroded crest of an anticline. It may be said to take its origin in two small streams, which enter the spacious cirque at the eastern base of Browning's Pass. The more southerly of these creeks enters from the Hall Glacier by a fall 120 ft. high, while the more northerly descends tumultuously from snow-covered talus slopes near Pope's Pass and from the couloir to the east of Mount Pope. Only a small portion of the Wilberforce is within the area now being discussed, our work including the southern watershed of the river as far as the Gibson or central fork of the Stewart, and the northern watershed as far as Cronin Creek. A number of streams enter the Wilberforce within this distance on the south side. The Griffiths, Gifford, Grave, and Hall Creeks all rise in small glaciers descending from spacious snowfields, subsequently to be described. Cronin Creek flows from a small snow-filled valley.

An excellent view of the broad valley of the Upper Wilberforce exemplifying the main features of the river is to be obtained from the summit of Browning's Pass. The U-shaped valley with a broad flare on either side is deeply filled with coarse glacial *débris*, which is rapidly being eroded by the swift-flowing stream. This fluviatile incision has cut into the bottom of the glacial *débris* on alternating sides, sending the river against the smooth cliffs of solid rock—the ancient glacial wall. Modern flood plains border the stream at various places, from which terraces often ascend at intervals to the level of the former glacial valley floor.

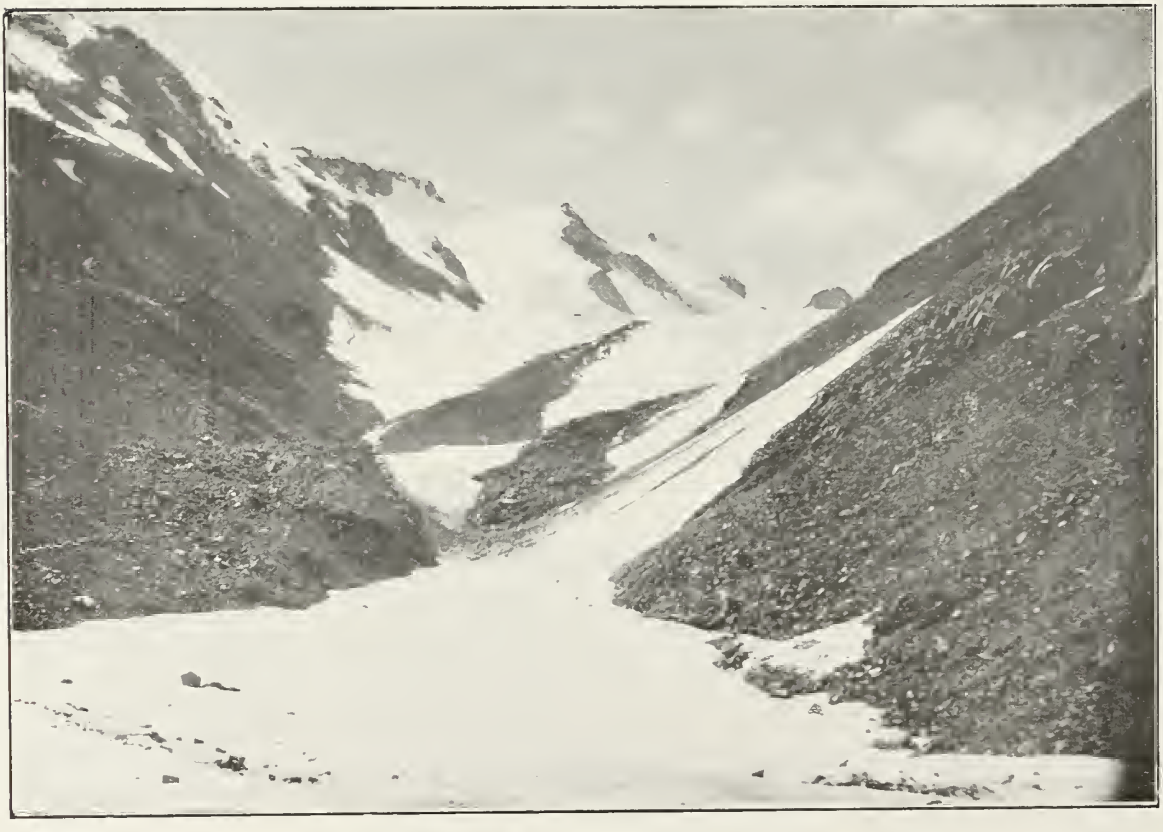
The flow of all the streams within the Hokitika area, like that of streams of other parts of New Zealand, varies greatly with the season of the year, whether the snow is melting or not, and, of course, with the condition of the rainfall. During the heavy rains the streams rapidly rise, but when once the weather clears they abate with marvellous rapidity. Many of the streams were gauged by the Geological Survey staff during the past summer, though owing to the frequent changes in the volume of the water a single observation is not of great value, and the gauging to be of permanent value should be carried on continuously for a number of successive years. The following tabulation sets forth the approximate discharges of the several streams measured:—

| Stream. | Date. | Condition of Water, and Remarks. | Average Velocity of Current. | Approximate Estimate of Total Amount of Flow. |
|---|---|---|---|---|
| | 1905. | | Feet per Second. | Cubic Feet per Second. |
| Hokitika River, at Kanieri Bridge ... | July 14 | Water below normal ... | 3·58 | 3,451 |
| Hokitika River, at Longford* ... ... | Aug. 1 | Higher than normal ... | 4 | 5,530 |
| Hokitika River, at Kanieri Bridge ... | Oct. 7 | Very low ... ... | 3·14 | 2,383 |
| Kanieri River, at outlet of Lake Kanieri | April 26 | Slightly lower than normal | 4·01 | 122·5 |
| Kanieri River, just above bridge on road to Kokatahi | July 14 | Normal ... ... | 3·04 | 398 |
| Kanieri River, at outlet of Lake Kanieri | „ 18 | Slightly lower than normal | 3·61 | 119·1 |
| Kanieri River, at outlet of Lake Kanieri | „ 25 | After very heavy rain, with abnormally high water | 5·78 | 499·5 |
| Kokatahi River, at Kokatahi Bridge ... | Aug. 1 | Higher than normal ... | 4 | 1,648 |
| Kokatahi River, at Kokatahi Bridge ... | Oct. 9 | High ... ... | 4·73 | 3,800 |
| Teremakau River, at Griffin Bluff ... | Sept. 21 | Exceptionally low ... | 6 | 4,500 |
| Arahura River, at Railway Bridge ... | Aug. 4 | Water very low ... | 4·79 | 855 |
| | 1906. | | | |
| Arahura River, opposite the Styx shelter hut | April 15 | Minimum flow for time of year | 2·5 | 92 |
| | 1905. | | | |
| Hunt's Creek, at mouth ... ... | Oct. 5 | Ditto ... ... | 4·2 | 154 |
| | 1906. | | | |
| Harman Stream, at crossing of track ... | April 15 | „ ... ... | 3·3 | 43 |
| | 1905. | | | |
| Taipo River, below Hunt's Creek Junction | Oct. 5 | „ ... ... | 4·5 | 600 |
| Styx River, just above its junction with the Kokatahi River—290 ft. above sea-level* | July 29 | Below normal ... ... | 2·8 | 266 |
| Mahinapua Creek, at Atkinson's farm ... | „ 31 | Normal, or perhaps a little below normal | 1·13 | 282 |
| | 1906. | | | |
| Stewart River, above junction of Wilberforce, and below junction of Griffiths | April 3 | Very low ... ... | 3·5 | 168 |
| Wilberforce River, at Sebastopol Point, above the junction of Stewart River | „ 3 | River very low ... | 2·6 | 142 |
| Wilberforce River, quarter-mile above Cronin Creek | „ 14 | „ ... | 2·2 | 45 |

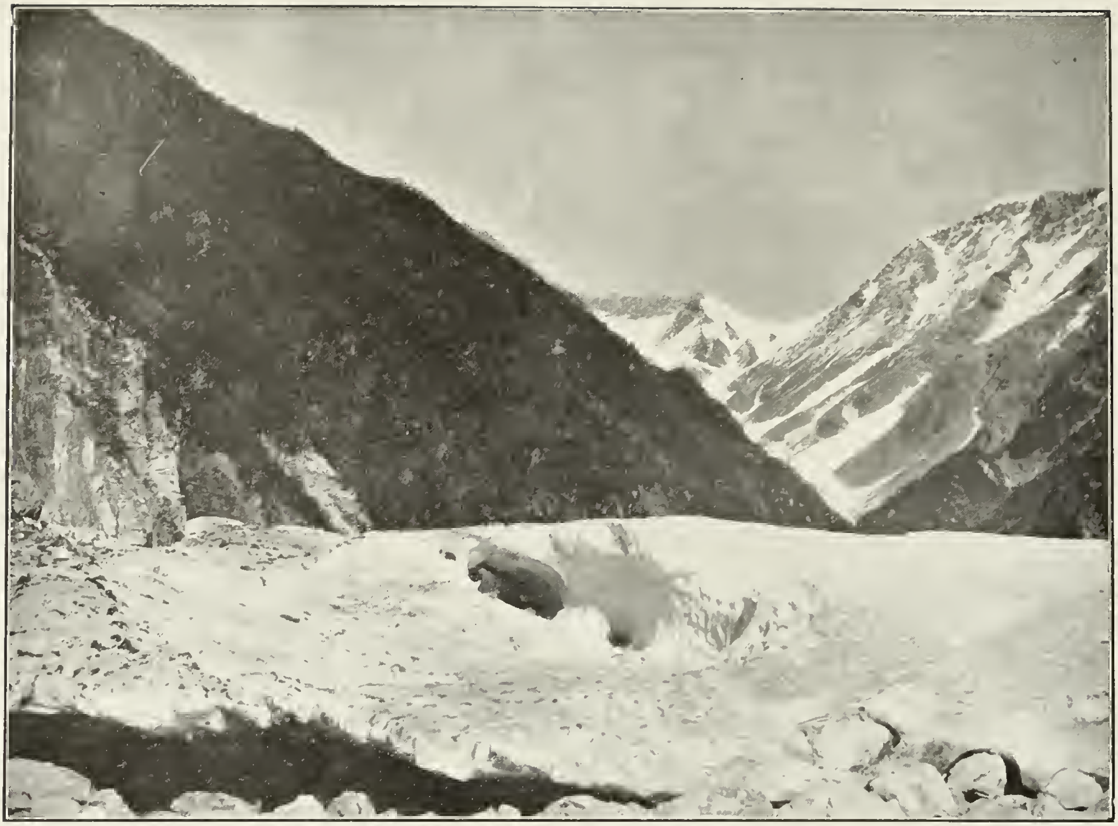
* This result is only approximate.



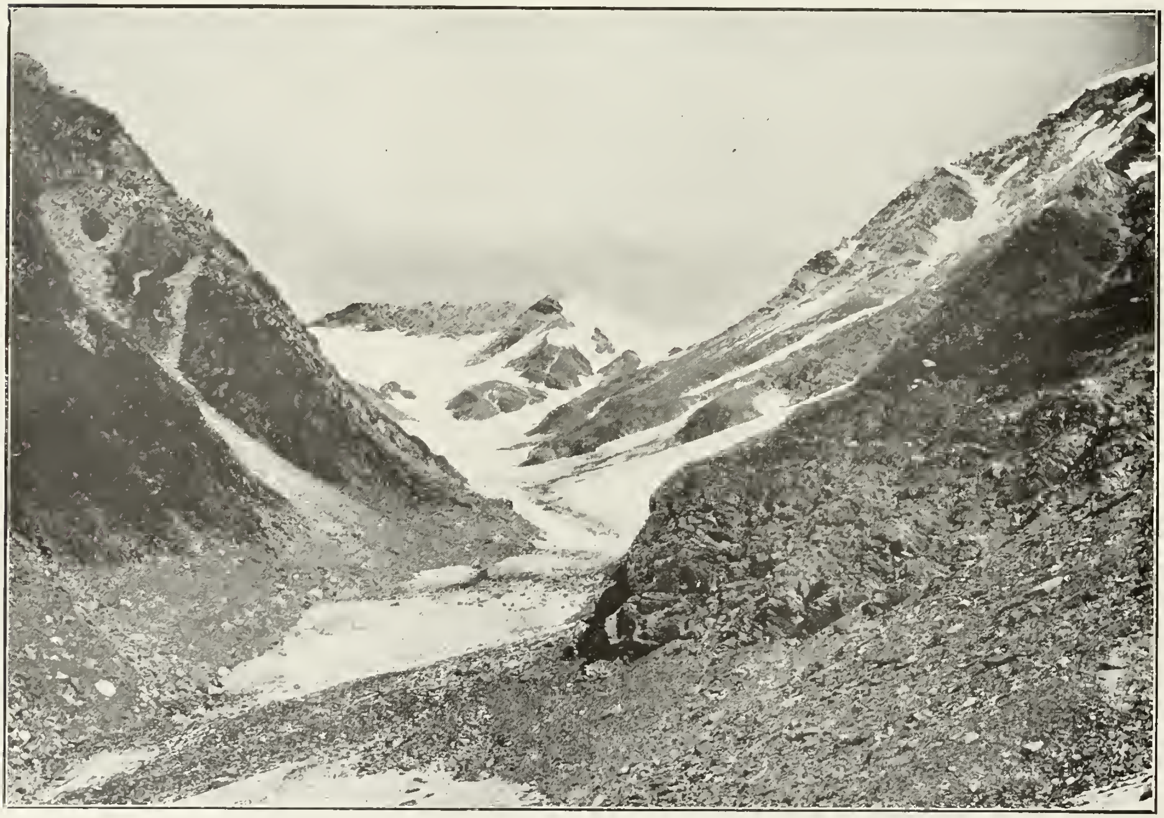
The Head of Griffiths Glacier.



The Moraines of Griffiths Glacier.



THE SNOUT OF THE GRAVE CREEK GLACIER.



THE UPPER PART OF GRAVE CREEK GLACIER, SHOWING MORAINES.

## The Glaciers of the Area.

The small glaciers now to be seen in the area covered by the present bulletin are but the remnants of features formerly of immense size and power. Compared with the large piedmont glaciers in South Westland and South Canterbury, the area under review shows no ice rivers of any magnitude. Their erosive power is in general slight or lacking altogether, though their transporting capacity is relatively greater. It is very probable that the ice streams are at present somewhat larger than ordinarily owing to the somewhat abnormal meteorological conditions, resulting in an increased precipitation and a decreased temperature, which have prevailed during the last few years. Many of the small mountain stream beds which in warm seasons would be quite bare were at the close of the past summer (1906) filled with hardened snow almost of the consistency of ice. These were to be found at the head of almost every stream in the alpine zone which ascends above 4,000 ft. and is surrounded by mountains of 6,000 ft. and over. Of course, such accumulations of snow can hardly be spoken of as glaciers, but in addition to these there are undoubted ice streams in the area, which are permanent and slightly corrosive in their action, and which carry moraines.

Probably the greatest ice centre in the locality under discussion is the snowfield lying on the main alpine divide between Mount Walter on the north and the slopes of Mount Keddel on the south This snowfield is a little over half a mile in every direction, and in it rise some of the largest glaciers in the area—the Gifford, the Grave, and the Hall Glaciers. Into this snowfield small glaciers, which unite laterally, descend in small séraced ice-falls from large areas of *névé* high up on the surrounding mountain sides. This snowfield is not level, but has a gradual descent from Mount Walter south-eastward. Its altitude at its north-western end is some 5,930 ft., while below Mount Keddel it is about 150 ft. lower. The peaks surrounding the snowfield rise to heights between 6,000 ft. and 7,000 ft. The bergschrunds occurring near their junction with the snowfield are of only minor importance. The snowfield at the top of the Gifford is seamed with crevasses, which, though narrow, descend to great depths in blue ice.

The Gifford Glacier descends with a gradual inclination from the snowfield, the descent in the mile and a half of its course being some 1,350 ft. Minor crevasses occur in the course of the Gifford Glacier, but in general they do not compare in magnitude with those towards its junction with the snowfield. The moraines carried on its surface are inconsiderable, and are most noticeable where high-grade lateral glaciers descend in crescentic shapes from the *névé* on the ridges radiating from the main divide. As a rule, these lateral glaciers towards their heads descend in sharp ice-falls, exhibiting magnificent seracs from small permanent ice blocks perched high on the mountain side. The most important of these lateral glaciers is one which falls from a high ice-clad saddle at the head of the Griffiths Valley.

The descent from the top of the Grave Glacier to its present snout is a steep one, especially just below the cornice at its head. The total drop is 2,500 ft. in a distance of a little more than one mile and a half. The snout of the glacier at present is undoubtedly very much in advance of its ordinay position. The Grave Glacier is a typical ice stream, exhibiting with wonderful clearness the many characteristics of this interesting physical feature. The very small moraines brought down by miniature subsidiary glaciers form small medial moraines on the surface of the main ice stream, while the water issuing from the base is sparsely charged with rock-flour. A few crevasses at right angles to the enclosing rock walls seam the glacier, and miniature ice-falls enter from glacial slabs on the adjoining mountain sides. There are no small streams of water flowing within the ice, and consequently moulins are lacking. The steep walls bordering the ice river are beautifully smoothed in places, and show glacial striation.

The Hall Glacier in its lower part is practically a snow-filled valley, but higher up its course it is a definite glacier though it carries but little moraine, and apparently has no corrosive action judging by the absence of rock-flour in the water issuing at its base. The head of the glacier in the snowfield is at 5,940 ft. above the sea. Near its beginning several small peaks rise out of the snowfield, and, being completely surrounded by ice, are miniature nunataks. A glacier descends one of the tributary valleys of the north branch of the Kokatahi (Farquharson Creek), which starts within 200 yards of the head of the Gifford. It falls comparatively rapidly in an even descent, and continues down the stream valley for under a mile.

The Griffiths Glacier is probably the longest and most decided ice stream in the area at present being discussed. It is a typical piedmont glacier of secondary importance, having a total length from its inception in the *névé* to its terminal face of 140 chains and a width of 15 chains. The upper part of the glacier is profoundly crevassed, while numerous small ice-falls descend precipitously from the high ridges bordering the glacier on either side, or again slope more gently into the main stream. Several fine medial moraines with large angular fragments occur; one of these moraines is 15 chains long, though only 5 ft. or 6 ft. above the surface of the ice. The inclination of the lower sparsely crevassed portion of the glacier is more gentle than the upper part. Several small and unimportant nunataks appear through the ice at the top of the Griffiths Glacier, and break the monotony of the snowfield. Entering the Griffiths on both sides below the base of the glacier are several small streams which flow from permanent ice blocks or incipient glaciers, perched at lofty altitudes on the sides of the Cabot and Eliot Ranges.

Cronin Creek rises in a lofty saddle, Whitehorn's Pass, 5,697 ft. high. The upper part of this creek is a snow-filled valley, but it can hardly be spoken of as a glacier. Elongated permanent glacial blocks, however, occur high up on the sides of the bordering ridges, and from the terminal face of these, huge chunks of ice break off and are precipitated into the snow-filled valley beneath. Lower down the valley small streamlets which have their beginning in similar ice blocks join the Cronin.

The Gibson is formed by the union of two small streams. One of these which descends from Mungo Pass, notwithstanding that it is at a high altitude, can hardly be said to start in a glacier, though there is much hard snow in its valley. Its other upper branch, however, commences in a decided though small ice stream. South of the Gibson, on the main divide, outside of the limits of our present work, several large icefields were noticed. Prominent permanent ice blocks were observed on the slopes of Mount Harman and Mount Axis, and also on the eastern side of the Campbell Range. The head of the Harman starts in a small snow-filled valley of no prominence. The two branches of the Kokatahi flow from beneath small rudimentary glaciers which have advanced within the last few years.

The hardened snow of the snow-filled valleys melts *in situ* or descends by avalanche-like movement, while the glaciers have a more gradual movement. No exact measurements were made as to the rate of movement of the principal ice streams, though it was noticed to be relatively rapid. The crest of Mount Tera Tama is a small mass of hardened snow with a beautiful cornice towards the east. Avalanches of snow are of common occurrence at the heads of the various valleys incised in the higher parts of the mountains. These are sometimes of huge proportions, and bring down in winter, even to altitudes as low as 3,000 ft., large quantities of snow, which is not melted by the close of summer.

All the small ice streams in the area being described are the mere shrunken remnants of former much more magnificent features, and, as a rule, cover the base of the wide valleys through which they flowed with greatly accelerated motion in the period of ice flood. This fact probably accounts for the small amount of erosive power exercised by the glaciers; none of them, with the exception of Grave Creek Glacier, giving rise to rock-flour in the streams which leave their base. and in this case the production of rock-flour is probably due to the comminution of superglacial or englacial *débris* rather than to corrosion of the rock floor.

The huge ancient ice sheets have left a very decided impression on the configuration of the Hokitika area. The effect on the river channels has already been mentioned. Lakes and tarns formed partly through glacial erosion or amid glacial *débris* will be mentioned in another section of this chapter. The rocks have been smoothed in many places by the ice sheets, though on the whole the effect has been to roughen the topography rather than to level it. *Roches moutonnées* are to be seen at the head of the Arahura just below the Harman, along the Upper Wilberforce, and elsewhere, and smoothed rock surfaces along almost every stream and high up on the mountain sides at the altitude to which the former ice ascended. Glacial striæ on the solid rocks are very uncommon, but were especially noticeable on the edge of the small reservoir above Milltown. The rock at this point, a hard micaceous granwacke, was beautifully smoothed, and the deep striations on its surface ran in a direction of north 19° west, and were evidently made by ice descending in former times from the slopes of Mount Tuhua.

As will be seen by a glance at the map accompanying this report a great part of the country is covered by unstratified glacial *débris*. As is typical of this sort of material in all parts of the world, its surface is extremely irregular, broken, and hummocky. Definite terminal moraines are to be seen near the Kanieri Township, and at many places southward between that place and Ross. Lateral moraines are often met with, though not infrequently they are difficult to distinguish from terminal moraines. Many of the long morainic ridges seen along the road between Kanieri and Ross and between Kawhaka and the Teremakau are very probably lateral moraines, though this point is doubtful. Rounded or elongated mounds occur everywhere in the morainic material, one of the most prominent being the hill of mammilated outline which is crossed in going from the Hokitika - Christchurch Road to Kawhaka. The hill is distinctly drumlin-like in outline, and rises to an altitude of 550 ft. above the Teremakau River flat. More definite drumlins are the rounded hills of morainic material situated between the Kawhaka Creek and Lake Mudgee. Lenses of stratified material are to be seen everywhere in the glacial drift, but this is of the nature of a deposit by tiny streamlets flowing within the ice rather than by any prominent englacial or subglacial stream. Eskers or ridges representing the deposit of streams beneath or within the ice are apparently rare in the area now considered. A narrow ridge crossed on the track leading from the Milltown Road to Lake Kanieri may be one of these features.

## THE LAKES OF THE AREA.

The lakes of Westland are of great interest not only from their wonderful scenic beauty but because of their varied origin. They may be said to be of the following kinds:—

(1.) Small mountain tarns excavated by powerful ice streams descending from the *névé* at greater altitudes. These occur either in soft or hard strata, but are more common in the former.

(2.) Large lowland lakes formed by glacial excavation of a pre-existing stream channel. In this case the size of the lake will depend in general on the magnitude of the former stream. This sort of lake is usually dammed by morainic *débris*.

(3.) Lakes lying in irregularities in the morainic drifts. These vary from small ponds a few yards across filling ice-block holes to spacious sheets of water with an area of some square miles.

(4.) Lagoons or lakes lying close to the sea-shore and formed by the damming-back of the water of some stream entering the sea on a sandy beach. This damming is caused chiefly by the united action of a powerful current along the shore, and by the constant force of the waves. Æolian deposits also contribute to the formation of these barriers.

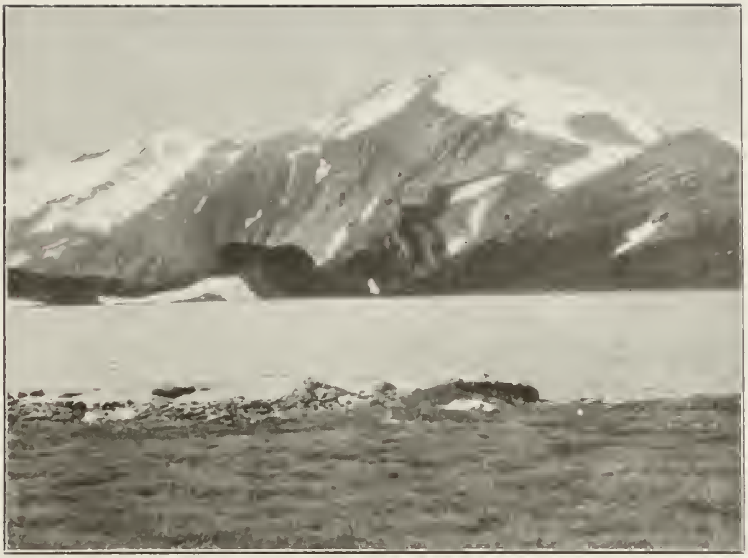
There are innumerable mountain tarns in the area now being described, especially in the lower mountains. The Wainihinihi peneplain, especially the Griffin Range portion, is dotted with many of these tiny ponds, while frequent mossy flats testify to still more which have disappeared by being filled with the *débris* of the surrounding hills. There is a small tarn on Mount Tuhua and another on Mount Turiwhate. On the Hohonu Range there are several ponds, the most prominent—Ruby Lake—lying at the head of Rubieslaw Creek. Ruby Lake, occupying a deep mountain corrie, has an area of about 10 acres, and an altitude above sea-level of some 2,500 ft. The high granite cliffs which surround it rise in places abruptly from the water's edge, while, again, talus slides of huge boulders relieve the mural precipices. The mountain scrub around the pond lends a charm to this beautiful mountain feature. The outlet at its south-eastern edge is over a steep cliff 150 ft. high, giving a fall of exquisite beauty, while below this fall a wide valley, bordered by steep cliffs on either side, leads downward at a very gradual grade for about two miles. Much of this valley is filled with swamp—the remnant of a former lake.

Lake Browning is a still better example of a mountain tarn. It is a beautiful sheet of clear water situated on Browning's Pass at an altitude of 4,490 ft. To the south-westward a low ridge separates the lake from the steep shingle slides which descend to the Wilberforce Valley, while to the north-eastward rise the rugged slopes of Mount Harman. Northward a broken line of hills, which, continuing to the westward and south-westward, rises to the snow-clad heights of the Twin Peaks and Mount Walter, shuts off the valley of the Arahura. Lake Browning formerly drained to the south-westward through the low flat bordering on that side, and then dropped abruptly into the Hall Glacier, and even to-day a cutting of 25 ft. would turn the water in that direction. Now it forms the headwaters of the Arahura and drains to the north-eastward, descending rapidly in a series of falls to the basin of the Arahura cirque at an altitude of a little more than 3,000 ft. The water near the shore of Lake Browning is shallow, though the centre is comparatively deep. Its surface area is constantly diminishing by the growth of small gravel fans brought down by tiny streamlets, which descend from the surrounding hills. At present its greatest surface dimensions are 25 chains by 20 chains, and its area some 38 acres. Low terraces about 5 ft. high at the outlet of the lake testify to the lowering of its level. Lake Browning was probably excavated by the union of powerful ice-falls formerly descending from Mount Harman and from Twin Peaks. From the ice plateau which then existed on the site of Lake Browning glaciers flowed towards the Arahura and the Wilberforce. A fine *roche moutonnée* is to be seen just to the south of the outlet of the lake.

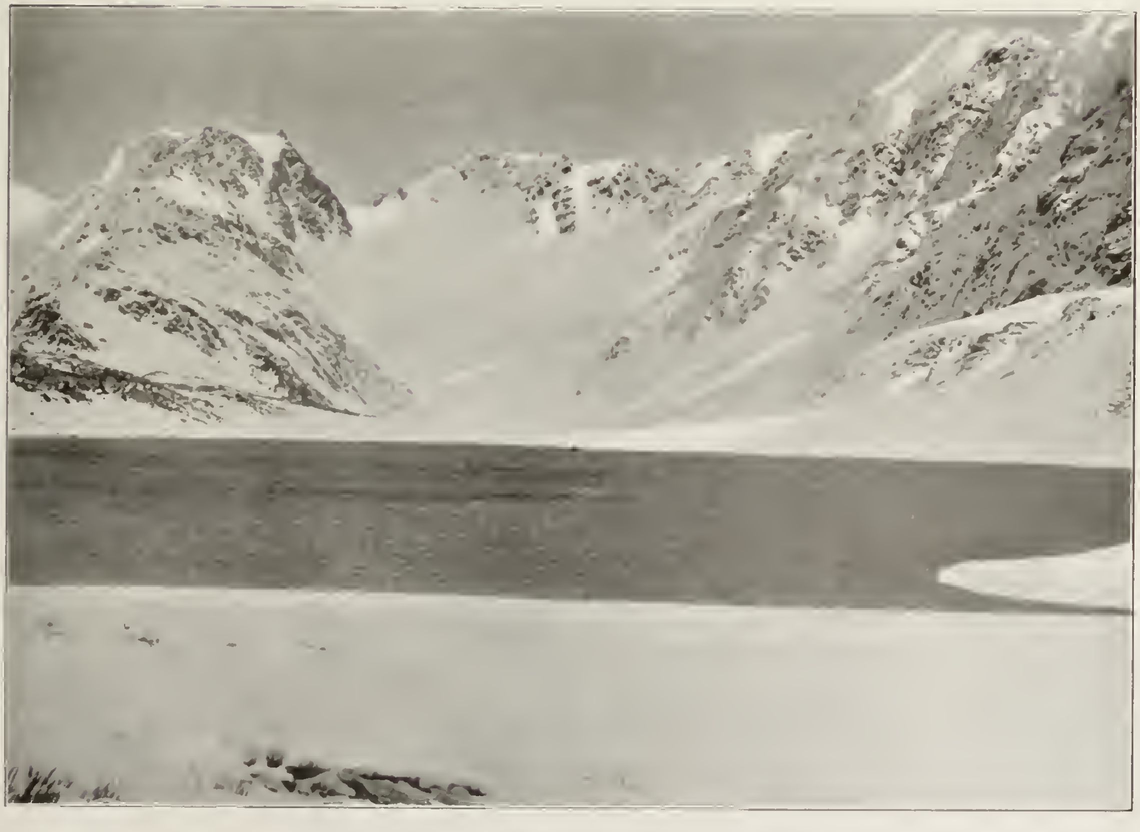
Of the second class of lake, Lake Kanieri is the only typical one in the area now being described. It has a length from north to south, in which direction its main axis lies, of five miles, and a maximum width of one mile and three-quarters, while its surface area is not under 3,600 acres. Its basin occupies an ancient river valley which has been profoundly altered by glacial erosion. Probably during the period of maximum glaciation a glacier descended the Styx River valley and sought an outlet northward through the north and south valley now occupied by Lake Kanieri. Glaciers also flowed from the surrounding hills on the east and west sides of the lake. The effect of the union of the several glaciers has been the formation of a very deep trough, with a relatively even and almost level bottom.

The water of Lake Kanieri is dammed back by an immense terminal moraine at its northern end. Formerly this moraine turned the drainage in the opposite direction from that of the preglacial river, and the water sought exit by a channel flowing, contrary to the old course, into the present valley of the Styx. Then there came an immense slip, or series of slips, from the slopes of Mount Brown, which closed the passage to the Styx, and the lake opened an outlet for itself along the old valley over the lowest part of the moraine.

Careful soundings were made of Lake Kanieri at frequent and regular intervals along definite lines, as will be seen by a consultation of the map accompanying this report Sixty-



Lake Browning, with Mount Harman in the Background.



Lake Browning, looking towards Hall Glacier.

one soundings in all were made, of which fifteen were under 100 ft., eleven from 100 ft. to 200 ft., eleven from 200 ft. to 300 ft., three from 300 ft. to 400 ft., six from 400 ft. to 500 ft., three from 500 ft. to 600 ft., and twelve over 600 ft., the deepest being 646 ft., followed closely by two soundings of 645 ft., and four of 644 ft., 643 ft., 640 ft., and 639 ft. each respectively. The surface of Lake Kanieri has an altitude above the sea of 422 ft., so that the deepest part of the lake is 220 ft. below the present sea-level, graphically illustrating the force of glacial erosion when superimposed on original fluviatile erosion. The soundings show that the lake is tub-shaped with sloping sides, and having at its deepest part a fairly flat bottom about two miles and a half long by half a mile wide. The paucity of soundings between 300 ft. and 600 ft. indicates a very steep inclination of the sides after a depth of 300 ft. is reached. Very probably the lake originally sloped steeply from both sides before the deposition of the gravels brought down by the entering streams. At the south end of the lake the depth of the water has also been lowered by material brought by in-flowing streams. The gradual slope of the north end may represent an original feature. A rocky ridge off the entrance to Big Bay, which apparently runs a little west of north, approaches in low water to within 1 ft. of the surface, but can hardly be considered as a serious irregularity in the under-water contour of the lake, seeing that it lies just to the west of the line joining the north and south headlands of the bay, which is nowhere more than 120 ft. deep.

Lake Kanieri is constantly losing in surface area by the entrance of broad gravel fans which mark the junction of every entering stream, especially on its lateral shores. Apparently the water of the lake formerly stood at a higher level, as there seems evidence of former shorelines standing above the level of the present water.

Lake Mahinapua is the largest and most conspicuous example of the third type of lake given above. The lake is for the most part surrounded by irregular glacial *débris*, but a portion of its western shore is bordered by an old sea-beach, which indicates that the lake is partially a lagoon representing the fourth class of lake before mentioned. Mahinapua is a shallow, mud-bottomed lake, for the most part under 12 ft. deep, and with a maximum depth of 29 ft. in ordinary conditions of water. As the altitude of its surface is about 6 ft., part of its bottom must lie some 23 ft. below sea-level. It has a maximum width of 75 chains, and a greatest length of 180 chains. Its surface area is about 940 acres. The almost unbroken forest which surrounds it makes Lake Mahinapua a particularly charming feature. It is drained by a creek of the same name, a sluggish stream flowing to the Hokitika River.

In addition to Lake Mahinapua there are many other lakes, such as Lake Mudgee and Lake Tarleton, which are ice-formed ponds lying in the glacial drift. The Totara Lagoon, a long narrow, shallow body of water, is a lake of the fourth class. It is dammed back by the sea-beach, and lies only a few hundred yards distant from the sea-shore. The position of its outlet has recently changed many times.

## SWAMPS OF THE AREA.

Swamps are of somewhat frequent occurrence within the area of the Hokitika Sheet, especially on the lowlands. Some of these represent lakes which have been filled by the *débris* brought by entering streams, while others are river-bottoms flooded from the adjoining streams. When the substratum of the swamp consists of a hard glacial boulder clay, or of the Blue Bottom, its drainage is particularly difficult owing to the impervious nature of the basement. The largest swamp in the area is Grove's Swamp, between the Hokitika River and Lake Mahinapua.

The sea-beach along the shore of the area being discussed is of particularly even and regular trend. Indentations are rare, and only occur at the mouths of the various streams. In general it may be said that the mouths of most of the rivers incline towards the northward. This is doubtless the effect of the prevailing current sweeping northward along the coast.

## PASSES AND SADDLES.

One of the most important of the physical features of Westland, owing to its isolation, is the alpine pass by which a highway might lead from the scattered settlements of the district to the large and prosperous towns and villages on the fertile plains of Canterbury. Within the area being here reviewed the mountain passes are high and difficult of access, and hence can hardly be considered as possible main routes of travel from ocean to ocean.

The principal saddle in the area under discussion is Browning's Pass, an elevated trough in which lies the basin of Lake Browning. The top of the pass has an altitude of 4,510 ft. It descends towards the south-west to the valley of the Wilberforce, and to the north-east to the Arahura. This pass is usually free from snow by the end of November or early in December, and remains bare for about six months. It is covered with a heavy growth of alpine grass. An unformed path leads up to Browning's Pass from the metalled track along the valley of the Arahura, while from the Wilberforce a narrow zigzag footpath has been constructed by the miners up the talus slide on to the low ridge bordering Lake Browning to the south.

Pope's Pass, between Mount Harman and Mount Pope, lies at the top of a snow-covered talus slope, near the head of the south branch of the Wilberforce. On the Westland side the pass descends by a shingle slope to the headwaters of Julia Creek, one of the branches of the Taipo River. Though the inclination from either side is fairly gradual, the elevated position of the pass—5,290 ft.—renders it unsuitable for an important highway. The route from the Wilberforce by Pope's Pass to the valley of the Teremakau, though rough, is of an easy gradient. During the past season Pope's Pass was never free from a thick coating of hard and apparently permanent snow. So much snow at this relatively low altitude is probably owing to the shaded position of the pass in the heart of the mountains. The rocky snow-free pass at the head of Cronin Creek, and probably leading from that stream into one of the branches of the Waimakariri, separates the Rosamond Range from Mount Isabella. Its altitude is some 5,697 ft. Griffiths Pass is a lofty mountain col, covered with ice, leading from the head of the Griffiths Glacier on to the much séraced ice of the small subsidiary glacier leading to the Gifford ice stream. The altitude of this pass is 6,410 ft.

A good route from the Wilberforce to the valley of the Hokitika is by Mungo Pass, situated at the head of the Gibson and Mungo Rivers, between Mount Park on the north and Mount Treadwell on the south. The pass is scaled with little difficulty from the Gibson or Canterbury side, while on the Westland side the descent to the valley of the Mungo is a very easy one. The pass is practically free from snow in midsummer, though there is some glacial material at a lower altitude in the Gibson Valley. Its altitude is 5,950 ft.

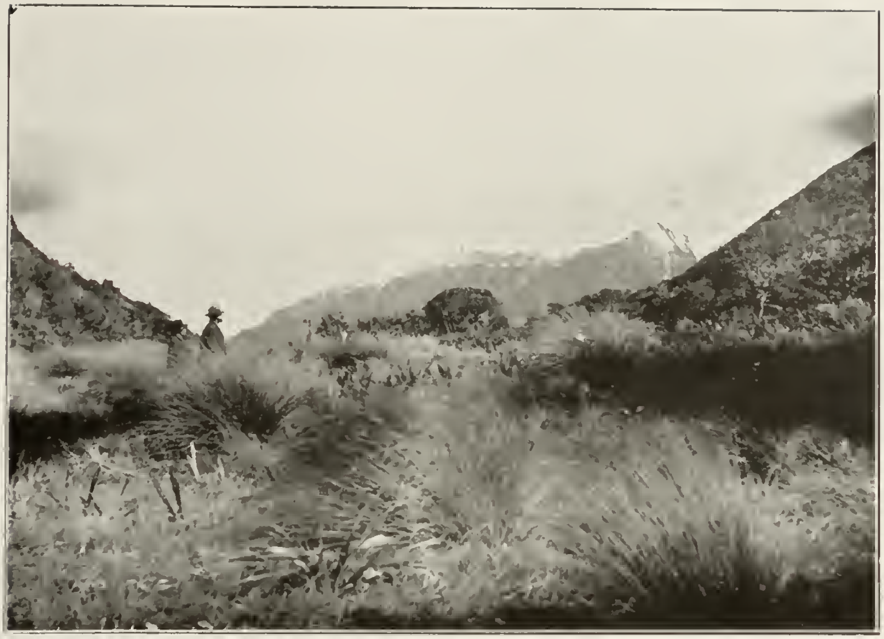
Clarke's Pass, at an altitude of 5,400 ft., can be easily ascended, and has always some snow on its surface. It leads from the Griffiths Valley to that of Clarke's Creek, one of the tributaries of the Kokatahi.

Styx Saddle is a typical U-shaped glacial trough, situated at an elevation of 2,500 ft., and leading from the Arahura Valley to the headwaters of the Styx River. This saddle is free from snow for practically the whole year, and in summer is covered with a heavy growth of native grass.

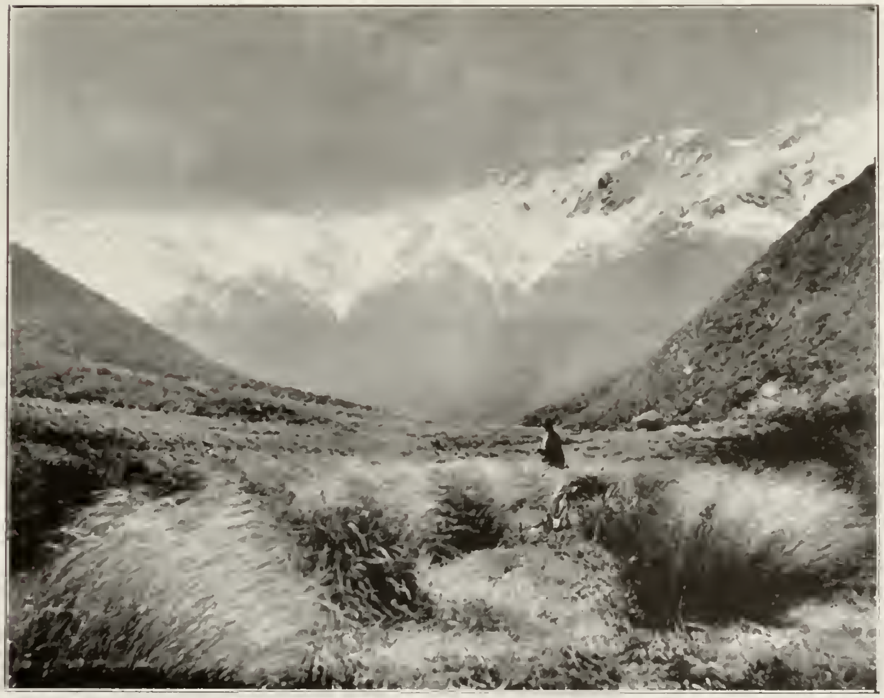
The lofty alpine passes are very frequently enveloped in fog, which sometimes renders them dangerous to traverse, while again in windy weather fierce gales sweep over them with tremendous fury.

## SPRINGS.

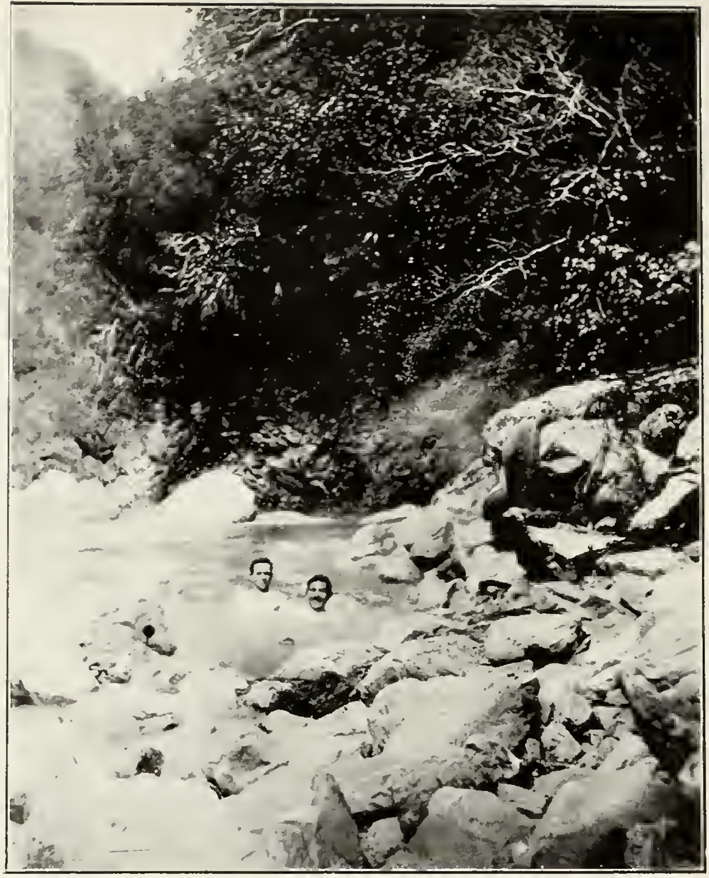
Phenomena of great interest to be seen in the alpine belt in Westland are thermal springs. These springs generally issue just at the edge of the streams, and during high flood are often completely covered by the river-water. The contrast between the springs of high temperature and the generally ice-cold river-water is very remarkable.



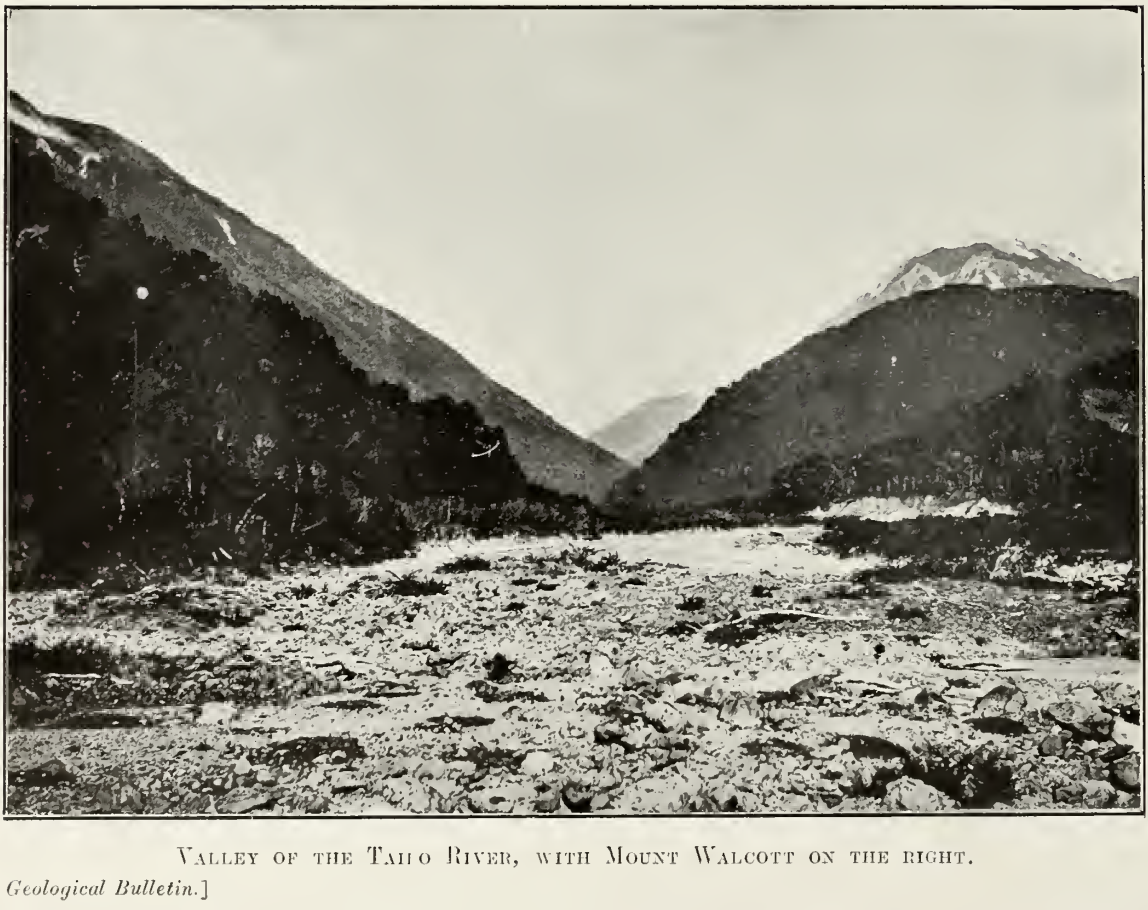
Styx Saddle, looking towards the valley of the Styx or Browning River.



Styx Saddle, looking towards Arahura Valley.



Fraser's Hot Spring, Taipo River.



Valley of the Taipo River, with Mount Walcott on the right.

The most important thermal spring observed in the Hokitika area is known as Fraser Spring, which occurs on the eastern bank of the Taipo River, about a quarter of a mile below the junction of Julia and Mary Creeks. For about 10 ft. or more immediately along the edge of the river, and partly within the stream, water at a temperature of about 180° Fahr. issues under some slight pressure from the sand and fine gravels. The water is heavily charged with hydrogen-sulphide gas, and deposits what is apparently a flocculent precipitate of silica on the boulders of the river-bed. The increased temperature can be noticed for quite 100 ft. along the river-bank; large boulders are warm on their undersides, and holes dug in the sand give off steam. For a mile and a half below Fraser Spring, or almost as far as the mouth of Dexter Creek, hydrogen-sulphide gas may be seen to issue at intervals along the bank of the Taipo. As the river is in general remarkably straight for this distance, and as the rocks exposed along the banks exhibit no regularity of structure, it is not improbable that the river here flows along a line of weakness in the strata, and that this fact may account for the hot springs rising to the surface from great depths in the heated interior. It was observed that the granwackes in the immediate vicinity of this supposed line of weakness were both silicified and pyritised. The following is an analysis of the water of Fraser Spring, which, however, is unavoidably diluted with river-water (results expressed in grains per gallon):—

| | Grains. |
|---|---|
| Silica ... ... ... ... ... ... ... | 6·4 |
| Magnesium sulphate ... ... ... ... .. ... | 1·2 |
| Chlorides and sulphates of sodium and potassium ... ... ... | 13·0 |
| Sulphuretted hydrogen ... ... ... ... ... .. | 2·4 |

Another hot spring appears on the northern branch of tho Kokatahi River, about two miles above the junction of the Crawford. The hot water bubbles up from the gravels and sands along the river at a temperature of about 120° Fahr. It is heavily charged with hydrogen-sulphide gas, and deposits silica. The flow of the spring is small, and it is not improbable that much of the hot water enters the Kokatahi below the gravel.

Cold-water springs are of common occurrence along all the streams, though they are rarely heavily mineralised. On Butcher's Creek, at the Bluespur, and at other places in the area underlain by the Blue Bottom, chalybeate springs were often seen, which deposit flocculent hydroxides of iron.

# CHAPTER V.

## THE ARAHURA AND KANIERI SERIES.

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### AGE AND CORRELATION OF THE TWO SERIES.

THE older sedimentary rocks appearing in the area now being discussed have been grouped under two broad headings, namely: (*a*) The Arahura series; (*b*) the Kanieri series. Of these, by far the most extensive and important is that to which the term "Arahura series" has been assigned. It may be stated at the outset that rocks have been grouped in a general way in the Arahura series which may or may not be referable to more than one of the great Post-Cambrian stratigraphical systems, or even to a Pre-Cambrian age. The Arahura series preserves throughout a fairly constant strike, averaging about north 30° east, which is approximately parallel to the main alpine chain. Limited to the westward by the wide belt of Tuhua intrusives, these rocks extend in apparently conformable sequence to, and beyond, the main alpine divide.

To the Kanieri series is referred the folded sedimentary beds in the immediate vicinity of Kanieri Lake, excepting a limited portion of the country covered by the Koiterangi series (coal-bearing strata), which unconformably overlies them, together with a small area of grauwackes occurring some distance to the south-westward of Lake Kanieri in the Hokitika River bed. The Kanieri series all lie to the westward of the main Tuhua granitic belt, though they surround the Mount Graham boss of this intrusive formation. The strata are disposed as a series of anticlines and synclines, but the strike is erratic owing to igneous intrusions, varying from north 36° west to north 36° east.

In the light of evidence afforded within the limited area examined, any attempt to correlate the Kanieri series with those of any particular section of the Arahura series is extremely difficult. Several considerations, however, seem to warrant especially the separation of the former from the older rocks of the Arahura series, viz:—

(*a*.) A difference of original lithological character can be apparently distinguished.

(*b*.) A difference in the general strike of the Kanieri series from not only the older part of the Arahura series, but the upper part as well, is visible.

(*c*.) A marked contrast is evident in the relative alterations of these rocks, although separated only by a comparatively narrow granitic belt. Those of the Kanieri series have been subject chiefly to contact metamorphism as the result of igneous intrusions, and the alteration is more or less local in extent. The lower or western portions, however, of the Arahura series show alterations due to igneous contact superposed on those due to an earlier and widespread dynamic metamorphism.

(*d*.) The position itself of the granitic belt is significant, and the intrusion would appear to have taken place along a plane of weakness marked possibly by a great structural break.

Subdivision of the rocks of these two systems by previous investigators, who have been able to draw their deductions from conditions obtaining over a much wider area than that now being considered, may here be briefly summarised.

Mr. S. Herbert Cox,* in referring to the rocks grouped in this report as the "Arahura series," considers that the schists which he groups as the "metamorphics" are to the eastward, overlain to all appearances unconformably by beds which are known as the "Maitai beds." The Kanieri rocks likewise he correlates with the "auriferous series" of Reefton, and regards them as one and the same as the Maitai division.

Mr. Alexander McKay, in his report on "Geology of the South-west Part of Nelson and the Northern Part of the Westland District," published in 1895, adopted the following grouping, viz.:—

*Metamorphic.*

Gneissoid schists.
(Note.—In part the "Tuhua formation" of the present bulletin.)
Mica-schists—
  Lower schists.
  Middle schists.
  Upper schists.

*Devonian.*

Slightly altered submetamorphic rocks.

*Carboniferous.*

Maitai series ("Westland formation" of Haast).

The metamorphics as high at least as the horizon of the "middle schists" are regarded as Archæan.† The most easterly rocks are classed as Maitai, because of the occurrence in them in Kelly's Creek, just to the east of the area covered by the Hokitika Sheet, of certain obscure fossils, supposed to be annelids, which are also found in the Mount Torlesse formation in eastern Canterbury—a classical Maitai area. Subdivision below the Maitai rocks has been based entirely on the lithological character, and Mr. McKay adds, "The lower beds of the Maitai series are not apparently separated from these [Devonian] by a marked unconformity, nor can any distinct boundary be determined between these and the schists [metamorphic] that underlie."‡

In general it may be said that the unmetamorphosed Kanieri series have in places a marked lithological resemblance to the upper part of the Arahura series. Both of these are classified by Mr. McKay as Maitai. This correlation may be quite correct, though the authors feel that, with the data at present on hand, no such correlation can be made with accuracy. It is expected that the detailed investigations to be carried out on the other sheets of the North Westland Quadrangle will throw more light on some of these obscure points.

### General Distribution of the Arahura Series.

As before stated, the rocks which have by far the greatest development in the area under review are those which have been grouped as the "Arahura series," the most continuous and typical section being afforded by the valley of the Arahura River, from which prominent feature the series receive their name.

A line drawn from the main bend of the Teremakau, about half a mile above the junction of the Rough Wainihinihi, in a south-westerly direction, and passing through the southern end of Kanieri Lake, fairly well indicates the western limits of the series. This sinuous boundary-line passes longitudinally through the valleys of the Rough Wainihinihi and Wainihinihi Creeks, crosses the Arahura River at the junction of Mount Brown Creek, and continues along the deep valley of the latter and that of Geologist Creek, falling into Kanieri Lake. The depression of erosion here outlined as occurring along this line constitutes one of the most striking physical features of the area. Extending to the east and south-eastward of the boundaries delineated, the Arahura series forms the rocks of the great deeply dissected Wainihinihi peneplain, the more elevated country of the alpine divide, and also the region extending from the eastern aspect of this great physical feature to and beyond the limits of the area examined.

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* New Zealand Geological Survey Report, 1875.

† "Rocks of Cape Colville Peninsula" and Other Parts of New Zealand, Vol. ii, page 198.

‡ Mining Reports, 1893, C.-3, page 172.

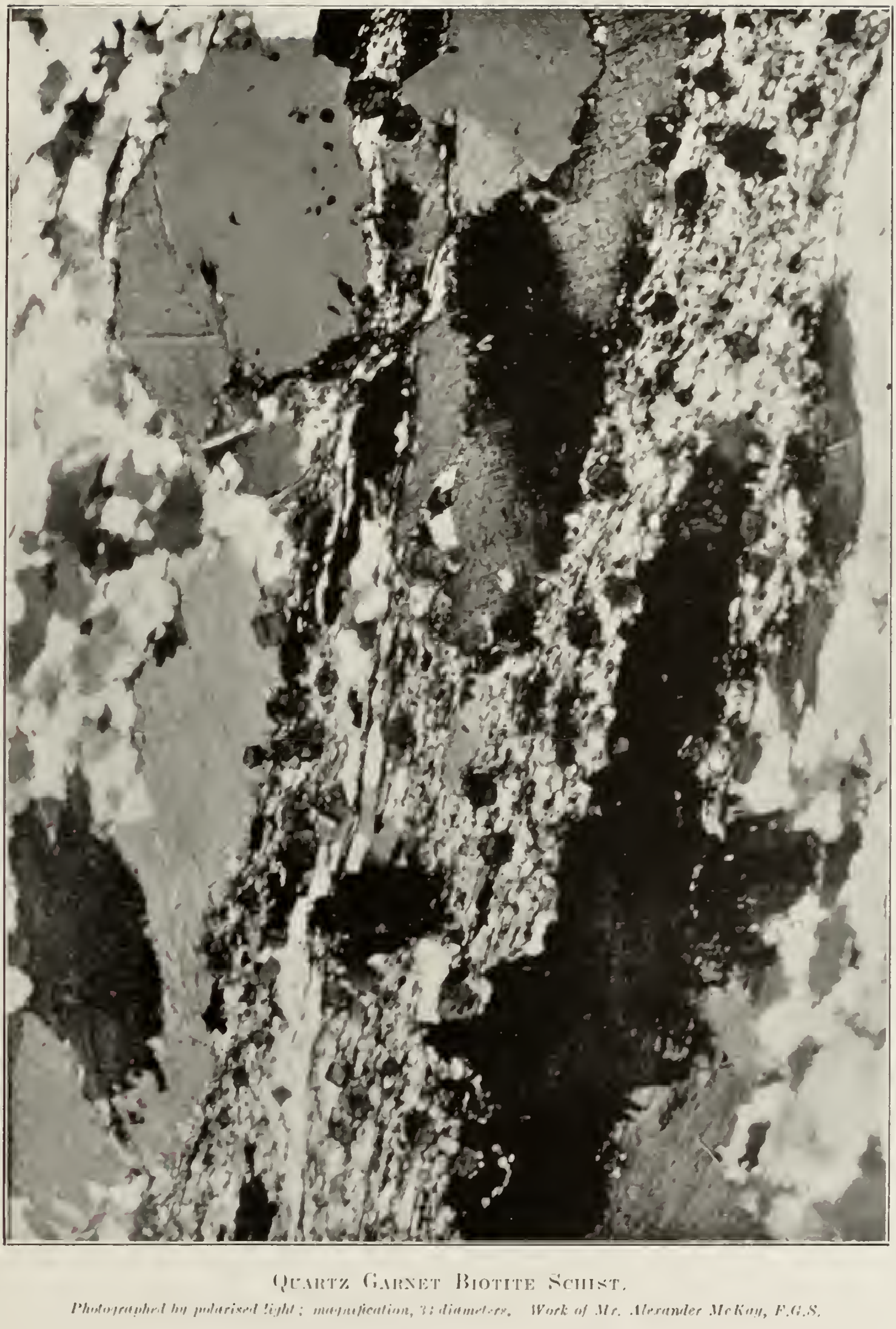
## General Structure of the Arahura Series.

The most characteristic structural feature of the Arahura series is the general uniformity in strike which the rocks exhibit throughout the whole area, and, although local irregularities occur in many places, it may be said to vary in general from north 10° east to north 50° east. The dip, which is usually to the eastward though sometimes to the westward, is always at high angles from 45° to 90°. Broadly viewed, the whole series may be regarded as forming a great synclinorium, probably including in the area of pronounced metamorphism many isoclinal folds, and in the area of comparatively unaltered sediments more regular folds. In the typical section afforded by the Arahura River valley, the main central axis of this great synclinorium is distant about six and a half miles from the Tuhua granitic belt lying to the westward, and likewise some six miles from the crest of the main alpine divide lying to the eastward. The plication of the strata has been most complex, and, though the longitudinal folding expressed in the great series of troughs and arches which make up the synclinorium is by far the most important corrugation which the strata has undergone, very often transverse folds occur which give the synclinals and anticlinals a slight pitch to the south-westward or north-eastward in the direction of longitudinal folding. A definite pitch of these longitudinal folds was seen at various points—among other localities may be mentioned the foot of the gorge of Griffin Creek, near the Christchurch Road. As before mentioned the Arahura series presents no definite unconformities of magnitude, although there appears to be some slight evidence of a structural break at a point in the Arahura River valley about two miles below the third gorge. The position of this possible unconformity has been indicated on the map accompanying this bulletin.

Although considerable minor faulting has resulted from the several orogenic movements which have given the strata their present deposition, no great structural faults are evident within the actual limits of the area, with the exception of the great fault, which has already been referred to in this report, with a general easterly and westerly strike in the Teremakau Valley. Minor faults are to be seen in almost every part of the Hokitika Sheet, as well as in the Wilberforce area. They are very evident near the mouth of Grave Creek, near the head of the Wilberforce River, along the Taipo, and at many other points.

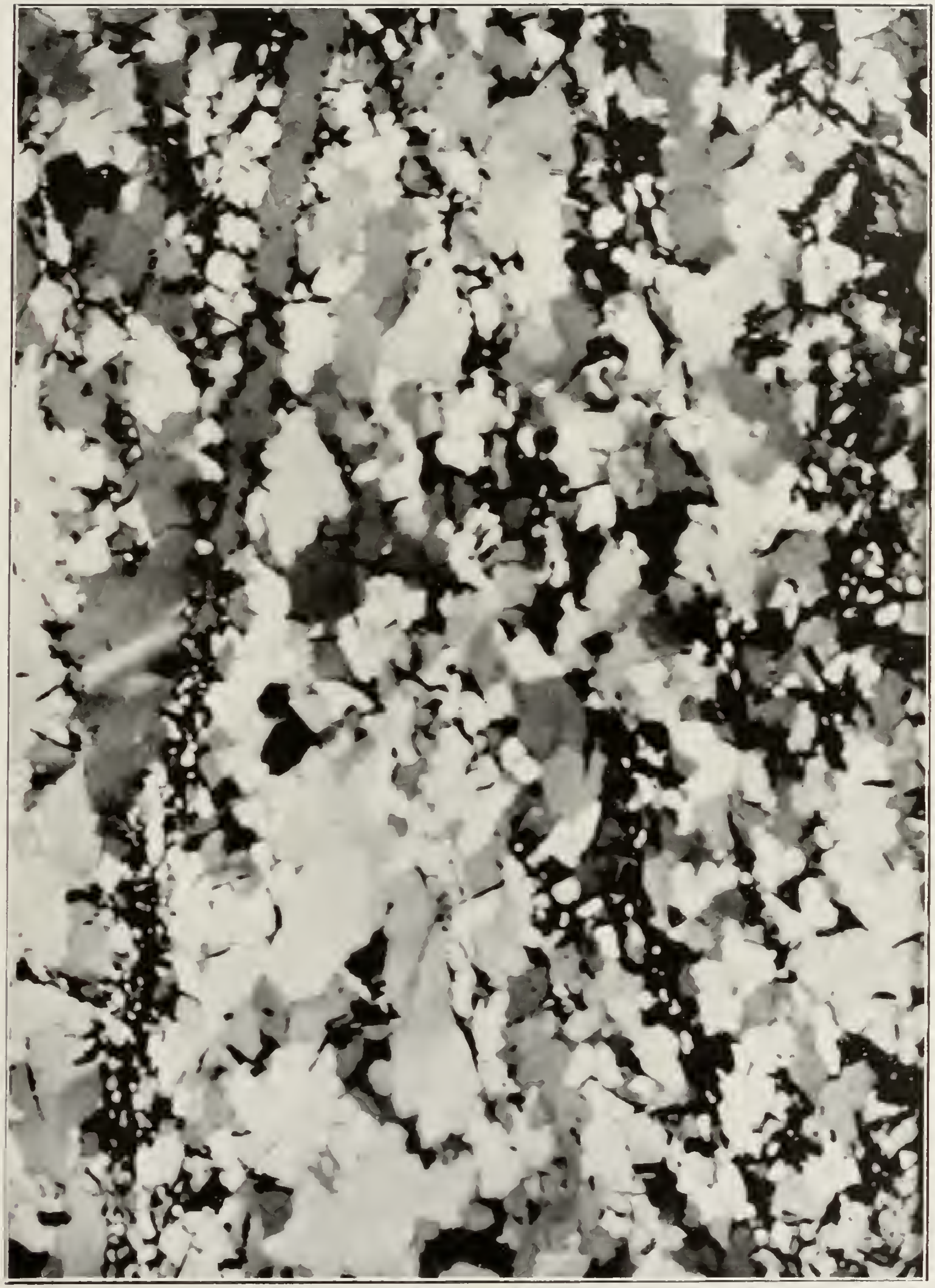
## Petrology of the Arahura Series.

The western portion of the series consists of schists and phyllites, while the eastern part is composed mainly of grauwackes and argillites. The most highly metamorphosed rocks occur in the vicinity of the Tuhua intrusives, and a very gradual transition from schists to phyllites, and from these to comparatively unaltered sediments, is apparent as the strata are followed in an easterly direction. Occupying an approximately median position in the schistose area are the persistent and well-marked intrusions of the Pounamu formation, which will be fully discussed in another chapter.



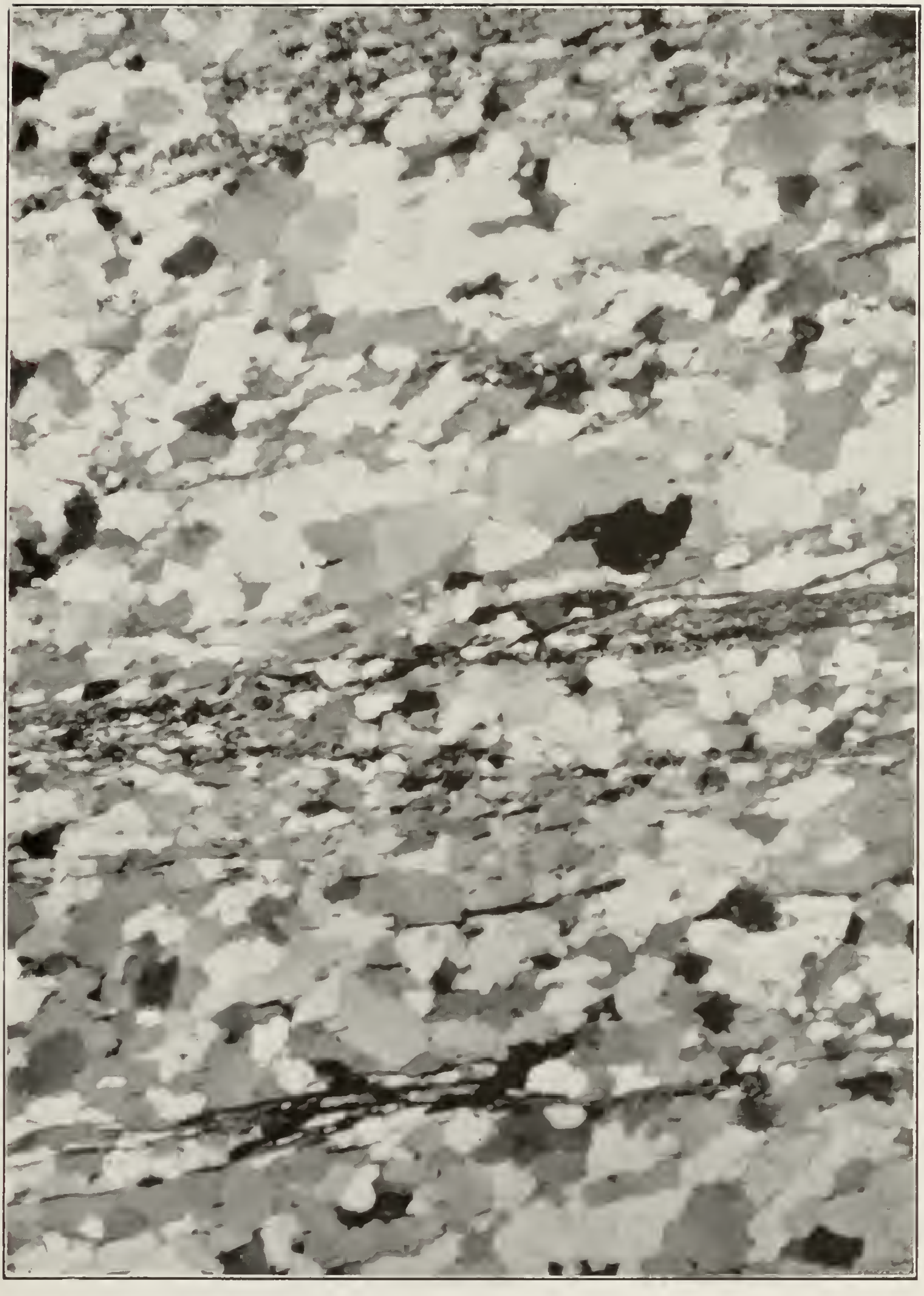
QUARTZ GARNET BIOTITE SCHIST.

*Photographed by polarised light; magnification, 34 diameters. Work of Mr. Alexander McKay, F.G.S.*



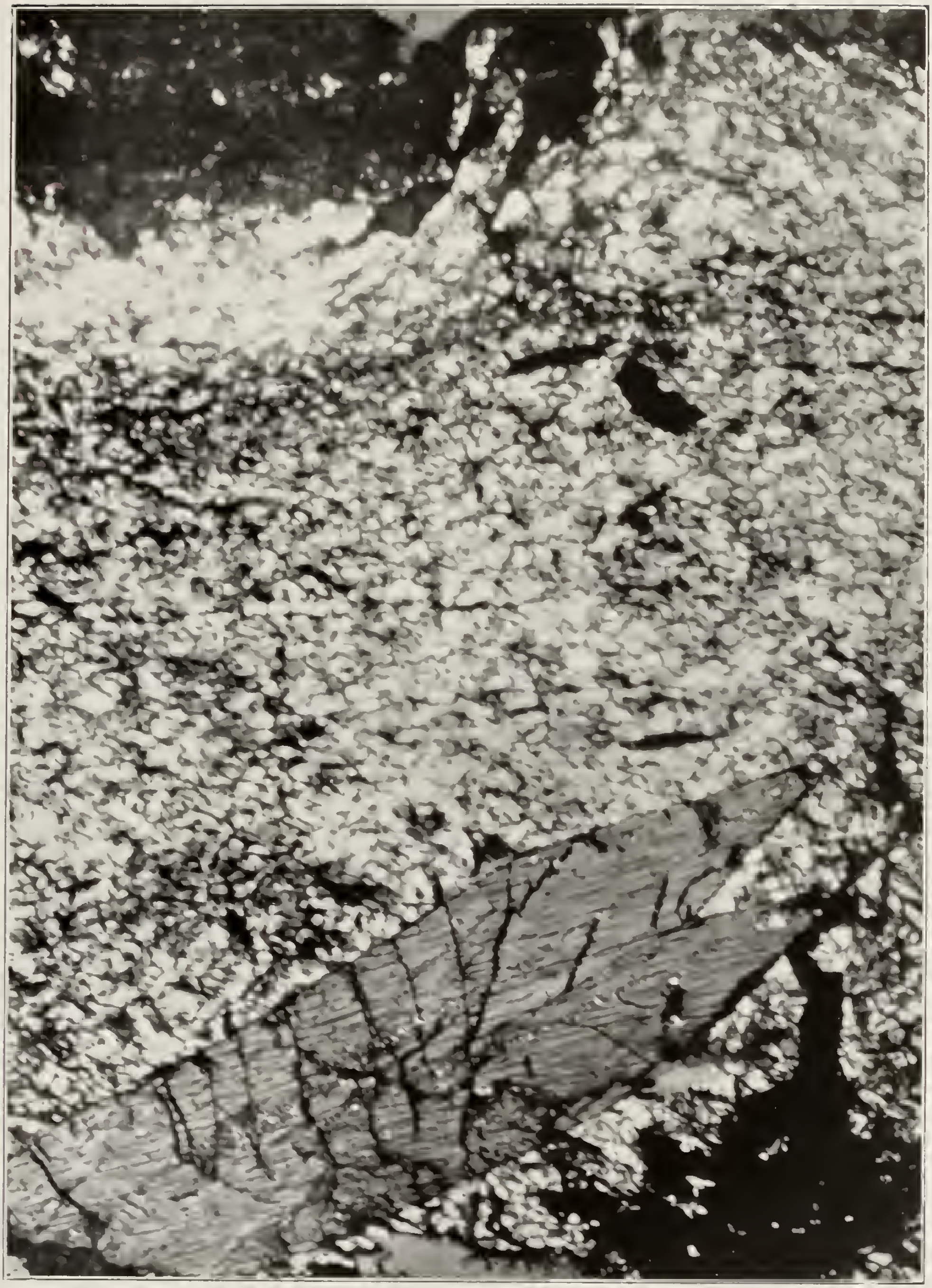
QUARTZ BIOTITE SCHIST.

*Photographed by polarised light; magnification, 33 diameters. Work of Mr. Alexander McKay, F.G.S.*



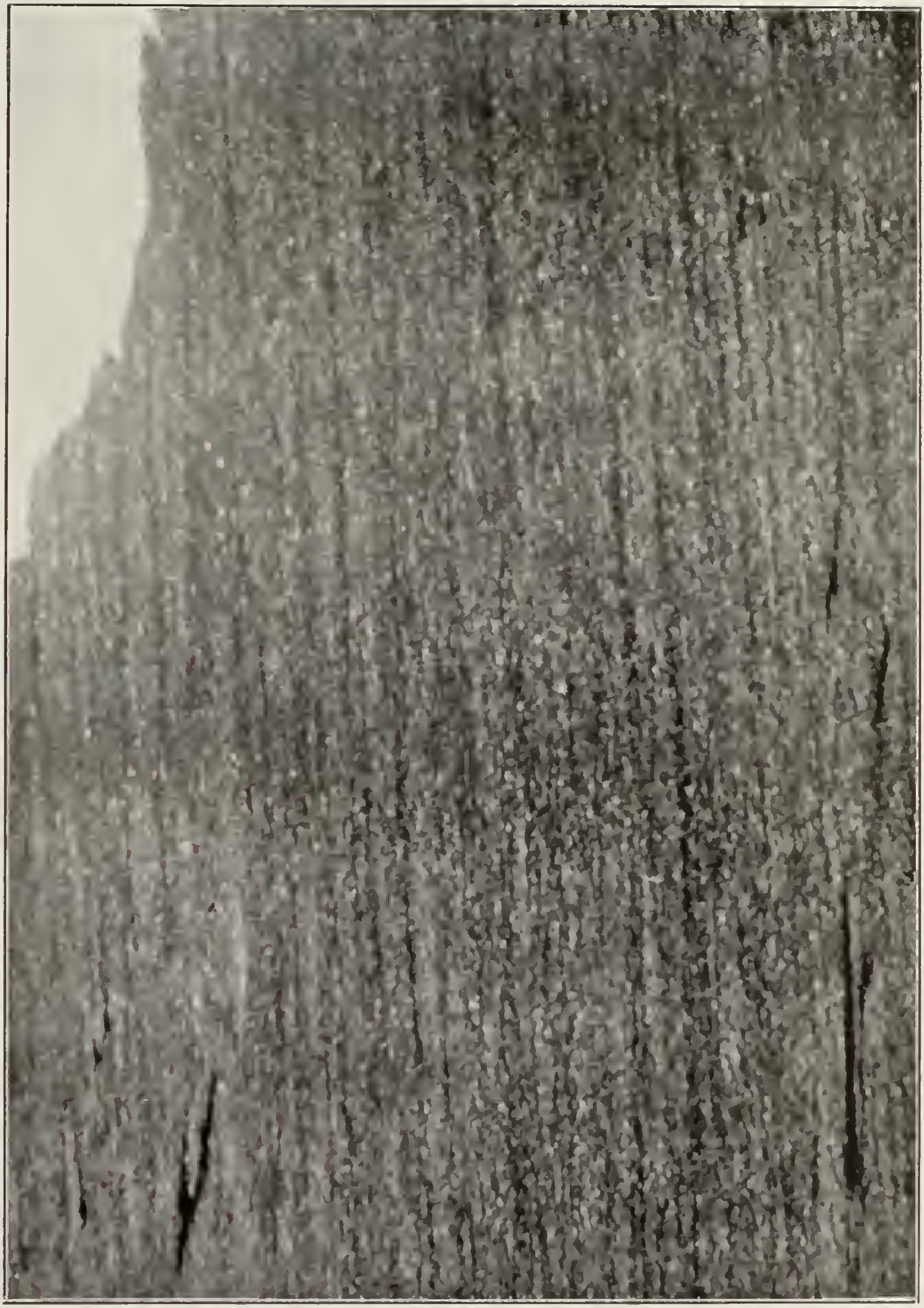
GARNET MICA SCHIST.

*Photographed by polarised light; magnification, 33 diameters. Work of Mr. Alexander McKay, F.G.S.*



GREEN AMPHIBOLE QUARTZ SCHIST.

*Photographed by polarised light; magnification, 33 diameters. Work of Mr. Alexander McKay, F.G.S.*



PHYLLITE.

*Photographed by polarised light; magnification, 33 diameters. Work of Mr. Alexander McKay, F.G.S.*

The western six miles of the series, which include the schists and phyllites, cover the rocks which have heretofore been grouped by the Geological Survey as the lower, middle, and upper schists, but it is doubtful if this subdivision can be maintained except as marking merely the degree of metamorphism. It is very probable that the schists may be many times repeated owing to the intense plication of the strata, and this fact may account for the recurrence of beds of certain varieties of schists.

The metamorphism of the area generally must be attributed to great dynamic agencies, while in the vicinity of the granitic intrusions the effects of contact metamorphism have doubtless been superposed. The transition eastward to comparatively unaltered sediments is a fairly gradual one, although bands of coarse-grained rocks occurring within the eastern portion of the area of more pronounced metamorphism are apparently much less affected than bands of very fine-grained rocks lying still further to the eastward. A broken line indicates on the map the arbitrary boundary between the western metamorphic area enclosing the schists and the eastern area of comparatively unaltered sediments.

### (1.) *The Schists.*

The schists present a considerable petrographical variety, more especially in the middle horizon of the metamorphic area. The following are of most frequent occurrence:—

(*a*.) Gneissic schists.
(*b*.) Biotite-schists, with garnet, zoisite, and epidote.
(*c*.) Banded quartz-mica schists, with garnet or zoisite and epidote.
(*d*.) Amphibole-quartz schist, usually with biotite, and often with garnet, zoisite, and epidote.
(*e*.) Biotite-chlorite schists.
(*f*.) Phyllites and schistose grauwackes.
(*g*.) Various magnesian-silicate schists, the result of alteration by the Pounamu intrusion.

The latter (*g*) present a great variety, and are more particularly characterized by the presence of chlorite, serpentine, talc, amphiboles, dolomite, muscovite, and magnetite, and are more conveniently discussed as a metamorphic aureole in connection with the Pounamu formation.

*(a.) Gneissic Schists.*—These rocks, which occur as a belt between the Tuhua granites and the finely foliated biotite-schists, are of doubtful origin, and will be described in connection with the contact phenomena accompanying the Tuhua formation.

*(b.) Biotite-schists, with Garnet, Zoisite, and Epidote.*—These schists overlie and are fairly well demarcated from the gneissic schists, being usually finely laminated, dark-grey in colour, and displaying a silky lustre. They exhibit fissility to a marked degree, are friable, and easily weathered. The ramification throughout these schists of thin lenticular veinlets of quartz is a conspicuous feature, while in their lower horizon garnets are frequently visible.

Under the microscope the rock is seen to consist in the main of bands of quartz mosaic with a little calcite, biotite, fragmentary garnet, and finely disseminated magnetite, alternating with bands in which biotite disposed in streamy alignment encloses more definite plates of the same mineral. Large fractured fresh-coloured garnets disposed in "augen" structure are also present. At times the garnets give place in part or entirely to small prisms and granules of colourless zoisite and epidote. The garnetiferous rock as described is typically developed in Mount Brown Creek, near the westerly or lower part of the series, while the zoisite-epidote variety is characteristic of rock from the summit of Mount Brown. Both further to the north-eastward and south-westward these rocks occupy similar horizons. In the former direction they constitute the western flanks of McArthur and Griffin Ranges, the country in the lower reaches of the Taipo River and beyond to the Teremakau River.

*(c.) Banded Quartz-mica Schists, with Garnet, Zoisite, and Epidote.*—These comprise conspicuously banded, highly quartzose schists which form considerable rock-masses, and in places alternate with bands of the darker finely laminated variety of biotite-schists (*b*). At times they assume almost a gneissoid appearance, and again resemble a quartzite with the fine foliation planes glistening with biotite. They are frequently characterized by the presence of flesh-coloured garnets, varying from microscopic proportions up to perfectly formed individuals about ½ in. in every dimension. Macroscopically there are all gradations from the coarse-grained rock, practically a quartzite, to the finely laminated biotite-schist in which quartz, although an important constituent, is not conspicuous to the unaided eye. Sections cut from the highly quartzose mica-schists, resembling a quartzite, viewed under the microscope consist in the main part of quartz, which, although recrystallized into a mosaic, exhibits in places sedimentary characteristics. Within this quartz mosaic are included well-developed laths of secondary biotite, and chain-like bands and irregular bunchy aggregates of zoisite, minute colourless garnets, &c., and occasionally prismatic microliths of undeterminable character. Determinations of the less quartzose specimens from other localities show detrital quartz, orthoclase, and plagioclase, with secondary biotite, quartz, epidote, and zoisite. The feldspars exhibit alteration to sericite and calcite, while the biotite is occasionally chloritized.

Quartz-biotite schists are typically developed in the gorge of the Arahura River between Spencer's Creek and Price's Creek, and, occupying a similar position in the series, occur on the Styx River, and in the upper part of the Rough Wainihinihi, and in the gorges of Griffin Creek, and along the lower Taipo. These banded quartzose schists offer considerable resistance to river-erosion, more especially if their strike is transverse to the course of the stream, and it is in such localities that deep gorges and waterfalls not infrequently occur.

*(d.) Amphibole-quartz Schists, usually with Biotite and often with Garnet, Zoisite, and Epidote.*—These schists may probably be regarded as transitional forms between the various quartz-biotite-garnetiferous-ziositic schists already described, and the greater variety of highly coloured magnesian schists which owe their characteristic metamorphism to the Pounamu intrusion. In the hand-specimen amphibole-quartz schist is usually a well-foliated rock, in which greenish scales and fibres of amphibole are conspicuous with apparently a minor amount of quartz and biotite. Under the microscope the rock proves to consist in the main of quartz and amphibole, while epidote and biotite occur to a minor extent. The principal minerals—quartz and amphibole—are disposed in a more or less parallel alignment with the epidote as aggregates of minute granules. The range of this rock in the series is variable, depending on the width of the belt metamorphosed by the Pounamu intrusive. It outcrops prominently in the Arahura Valley, near the head of Price's Creek.

*(e.) Biotite-chlorite Schists.*—Most of the biotite-chlorite schists are finely laminated, dark-coloured schists, in which biotite and chlorite are, with quartz, the most characteristic minerals. Frequently the original sedimentary character of the rocks is still apparent. They differ from schists of group (*b*) in the absence of garnet and the relative infrequency of epidote and zoisite except as very minute granules. Under the microscope sections of the biotite-chlorite schist show the development of parallel lamination, the laminæ consisting of finely grained aggregations of quartz with which is associated conspicuous biotite with sericite, chlorite, and the accessories magnetite and titanite. A fine-grained blackish material may be carbonaceous. The biotite-chlorite schists have their most conspicuous development in a fairly constant horizon across the sheet to the eastward of the Pounamu belt.

*(f.) Phyllites and Schistose Grauwackes.*—No hard line of demarcation can be drawn between the phyllites and various schists already described, and they especially resemble the biotite-chlorite schists, into which they grade insensibly. Nor, again, can they be definitely separated from the

comparatively unaltered sedimentary rocks to be hereafter discussed. Alternating with the phyllite on their eastern limit, and finally predominating over them to the eastward, occur schistose grauwackes.

Macroscopically the phyllites are fine-grained dark-grey rocks, exhibiting the silky lustre along the plane of stratification which is so characteristic of this rock generally. Under the microscope the principal minerals visible are quartz, sericite, chlorite with a little biotite, pyrite, and magnetite. In the hand-specimen the schistose grauwackes are coarse-grained greyish rocks, which often show faint partings in which biotite or chlorite are developed. Microscopically they are composed chiefly of large grains of quartz, orthoclase, and plagioclase set in a less important matrix of biotite, chlorite, epidote, finely comminuted quartz, and accessory zircon and magnetite. The large individuals of quartz and plagioclase and orthoclase are fractured, and the biotite of the groundmass is bent. The phyllites and schistose grauwackes have considerable development west of a line drawn through the Taipo River about a mile below the junction of the Seven-mile Creek, and crossing the Arahura at the third gorge in the vicinity of Newton's Creek. This line may be said to indicate the eastern limit of the metamorphic area. It will be observed that in the area covered by the metamorphic schists there is in general an alternation between coarser-grained rocks and finer-grained rocks as the area is followed from the westward towards the eastward.

### *Comparatively Unaltered Sediments.*

Following in apparent conformity the schists and phyllites of the western portion of the Arahura series is a great thickness of comparatively unaltered sedimentary rocks. They consist of all gradations from coarse-grained arkositic grauwackes to very finely textured argillites in frequent alternation, and with little variation excepting that in certain horizons the grauwackes predominate, and in others the argillites. The distribution of the less metamorphosed sedimentary rocks has already been sufficiently well indicated, as they form the whole of the area lying to the eastward of the arbitrary line which limits the eastern extension of the metamorphic rocks.

The comparatively unaltered sedimentary rocks vary in colour from grey or greenish-grey in the coarser-textured varieties to almost black in the argillites. The argillaceous rocks generally split readily along the bedding-planes, and on their surfaces frequently exhibit a faint silky sheen. In certain localities, more especially to the east of Browning's Pass, belts of exceedingly hard black mudstone occur, which, devoid of lamination and breaking with a splintery fracture, often resembles a compact fine-grained basaltic rock. Jointing more or less transverse to the bedding and at very irregular intervals exists throughout the whole area, causing both grauwackes and argillites to break in rough rectangular blocks. The grauwackes are always indurated, and in places highly silicified. When silicified very finely disseminated iron-pyrites may be detected throughout the mass of the rock.

Mention may be made of several interesting localities of comparatively unaltered sedimentary rocks. Immediately succeeding the more metamorphosed of the Arahura rocks, and having as their counterparts with these the schistose grauwackes, is a marked horizon of coarse-grained arkositic grauwackes which contain thin interstratified slaty bands, displaying a somewhat silky lustre. These arkositic grauwackes are especially apparent immediately eastward of the third gorge of the Arahura and near the Seven-mile Creek, on the Taipo. Very interesting are the curious breccias, which have a fairly wide distribution. They consist of a coarse grauwacke, in which isolated inclusions of fine-grained indurated argillite occur. These inclusions are angular, subangular, or lenzoid, and are often disposed in rudely parallel alignment. The origin of these rocks is probably explained on the assumption that the beds of coarser sediment, while in course of formation on the sea-floor, received fragments from beds of hardened mud close at hand, disrupted by the sea-waves.

Under the microscope the rocks, whether coarse or fine in texture, are seen to be remarkably uniform in mineralogical composition over the whole area. The more prominent clastic material consists of quartz, orthoclase, acid plagioclase, microcline, muscovite, biotite, titanite, and magnetite. Orthoclase frequently predominates over quartz, and is at times remarkably well preserved, showing Carlsbad twinning. The principal secondary minerals are quartz, chlorite, sericite, epidote, calcite, and pyrite.

The mineralogical composition of these rocks shows that the rocks of at least the eastern portion of the Arahura series have been, like the Kanieri series, derived from the erosion of a granitic or gneissic area.

### CONTENT OF THE KANIERI SERIES.

As previously indicated the rocks of this series all lie to the westward of the main mass of the Tuhua formation. Their relation to the great series of rocks lying to the eastward of the Tuhua formation has been already considered. Within the limits of the Hokitika Sheet they are not exposed on the surface over any considerable area, but doubtless underlying the younger Tertiary deposits of the coastal plain they have a fairly wide distribution.

The series includes arkositic grauwackes, argillites, minor bands of conglomerate, and schistose rocks. The latter are the equivalents of the grauwackes and argillites, metamorphosed by the intrusion of the Tuhua rocks. The more precise nature of the metamorphic rocks will be discussed in another section of this chapter.

### GENERAL DISTRIBUTION OF THE KANIERI SERIES.

From the accompanying maps it will be seen that these rocks exist as narrow belts on each side of Kanieri Lake, flanking the granitic mountains, Tuhua and Graham. On the eastern side of the lake isolated outcrops are inconspicuous features around the shores of the Milltown Reservoir and the upper part of the race flowing from that feature. They outcrop along several streams, entering Kanieri Lake from its north-eastern end as far as Camp Creek, and appear on the shore of the lake just south of Big Bay. On the western side of Lake Kanieri the most extensive area of the Kanieri rocks appears, where they form the mass of Conical Hill and the country constituting the watershed of Bluebottle and Butcher Creeks, with the exception of the small section covered by the Koiterangi or coal series. The rocks along the lower part of Kent Creek and Hooker Creek also belong to this group. On the western slope of Koiterangi Hill certain grauwackes, which are tentatively classed with the Kanieri rocks, lie unconformably beneath the Koiterangi series.

### GENERAL STRUCTURE OF THE KANIERI SERIES.

The strike of the rocks forming the narrow belt of the Kanieri series on the eastern side of Kanieri Lake has a general uniformity, though there are many minor departures from regularity. On the western side of Kanieri Lake the rocks are folded into a broad syncline, and dip in the main towards the Mount Graham boss from either side though not constantly. The apex of an anticline enters the western side of Kanieri Lake about half-way between the mouth of Hooker Creek and the Cave, and forms the main axis of the lake as far north as Hans Bay. The base of Lake Kanieri in consequence occupies the denuded crest of an anticline, which has been successively eroded by fluviatile and glacial erosion.

### PETROLOGY OF THE KANIERI SERIES.

Owing to the general uniformity in the mineralogical composition of the Kanieri series, it is necessary to suppose that the constituents of practically the whole series were derived from rocks of a generally similar lithological character, probably granites, granitic gneisses, or similar rocks.

As before indicated the beds include conglomerates, arkositic grauwackes, and indurated argillites, with, in the vicinity of the intrusive granites, the metamorphosed equivalents of certain of these rocks.

Megascopically the unweathered grauwackes are rocks of a greenish-grey colour and medium texture, in which quartz, feldspars, and muscovite are easily distinguishable. Under the microscope the clastic nature of these rocks is very apparent. The allothigenous constituents consist in the main of angular and subangular fragments of orthoclase, plagioclase, and quartz, with irregular plates of muscovite and biotite. These larger fragments are inserted in a finer-grained matrix of the same mineralogical composition. Both orthoclase and plagioclase (oligoclase to andesine) are often remarkably well preserved, but in places show alteration to sericite, calcite, and other secondary products. The quartz, clear and unstrained, sometimes contains definite lines of inclusions, many of which are fluid cavities. As minor constituents of the detrital material magnetite and ilmenite appear generally in a disseminated state. Small crystals of zircon and fragmentary apatite occur in the interstitial material, but are not prominent. Among the secondary minerals quartz is perhaps the most abundant, while sericite and carbonates (both calcite and siderite) have considerable development. Chlorite, epidote, and zoisite also occur, the two latter as minute chain-like aggregates. Pyrite is occasionally present.

The indurated argillites, which often show a silvery sheen on cleavage surface, are found when microscopically examined to possess the same mineralogical composition as the rocks already described. Some, however, consist of mineral matter in such an exceedingly fine state of division that even high magnifications yield little information as to their original character. The weathering of these to a hæmatitic product is frequently noticeable, but it is not so general as in the case of coarser sediments.

The conglomerates intercalated with the grauwackes and argillites are in both localities observed of a highly ferruginous appearance, the predominant colour being chocolate or purplish-red. The contained boulders and pebbles, which are fairly well rounded, consist almost entirely of ferruginous micaceous sandstone and argillite, which are identical with the weathered products of the prevailing rocks of the Kanieri series, while with these are occasional quartz pebbles. The existence of these beds has already been referred to as peculiar, and it has been suggested that they probably may be regarded as an intraformational conglomerate rather than a basal one.

The metamorphic rocks of the Kanieri series represent mica-schists, epidote-schists, and hornfels. Intermediate between these metamorphics and their unaltered equivalents are rocks in which the principal development of biotite is along certain planes of weakness, while the greater mass of the rock resembles rather the original grauwackes or argillite. Megascopically the mica-schist appears at first sight to consist almost entirely of biotite, but a closer examination shows that quartz is the main constituent. Under the microscope the rock consists in the main of a mosaic of quartz, with brown biotite, none of the finer interstitial clastic material remaining. Of the allothigenous constituents, however, remnants of fairly large quartz and feldspar individuals still persist, but the feldspars are throughout partially replaced by secondary quartz and muscovite. Only an incipient parallelism of the constituent minerals is apparent.

The most typical epidote-schists are those of fine texture, which present a silvery sheen and exhibit numerous isolated dark spots. Microscopically they closely resemble the finer-grained mica-schists into which they imperceptibly grade. The secondary products in this case include quartz, biotite, sericite, calcite, and more conspicuously epidote, which occurs in aggregates of small granules which give to the rock its characteristic spotted appearance.

The hornfels are dark, compact rocks, having a very fine texture and a splintery fracture. Excepting minute glistening points, probably biotite, and a few isolated fine grains of pyrite, the mineral constituents are unrecognisable in the hand-specimen. Microscopically the original characters of the rock are obscured, as it consists almost entirely of secondary material. Quartz and biotite form the greater portion of the mosaic, while colourless zoisite and epidote are present as granules and granular aggregates. Sericite, calcite, and chlorite occur in the main as replacement pseudomorphs after feldspars, while cubes and grains of magnetite are fairly regularly interspersed throughout the section. When more coarsely grained this hornfels passes into the finer-textured varieties of the biotite and epidote schist.

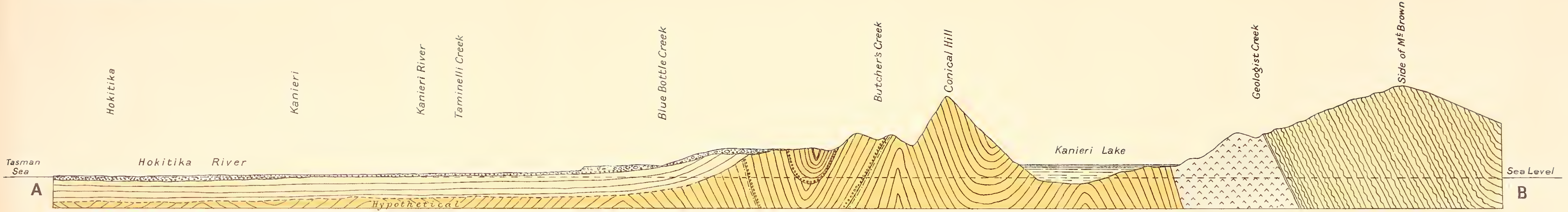
### SPECIAL AREAS.

In the watersheds of Bluebottle Creek and Butcher's Creek the strata consist of alternating beds of arkositic grauwackes and argillites, while with these are associated in certain localities minor bands of conglomerate. The strike is in places decidedly erratic, probably owing to the proximity of the Tuhua intrusives, and the dip also varies considerably, though it is generally to the eastward at high angles. A striking feature over the greater portion of this part of the country is the prevailing reddish or chocolate colour which the rocks assume on weathering. This is especially noticeable in the case of those of coarser texture, which decompose to hæmatitic micaceous sandstones and grits, but the same also extends to the argillites. It may here be observed that in the vicinity of the overlying Koiterangi series these rocks weather in the manner described to a much greater depth than do the rocks of the area generally, and it is possible that this is partly due to the strata having been permeated by iron-bearing solutions during the period of deposition of the coal-measures.

The occurrence of conglomerate bands in the Bluebottle Creek, about a quarter of a mile below the third branch on the north side, and also in Butcher's Creek, is peculiar, as such rocks do not appear elsewhere, as far as is known, in the Kanieri series or in any part of the Arahura series. Moreover, they here occur apparently interstratified with rocks which lithologically must be correlated with those of the Kanieri series, and which are separated by an unconformity from the pebbly conglomerate forming the base of the coal series. It may be that these should be regarded as belonging to a lower horizon in the coal series, and that they have been intricately involved with the older rocks; but of this there is no proof, nor do they resemble either the conglomerates of the coal series at Gentle Annie or at Koiterangi. Owing to the intercalation with definite Kanieri rocks these conglomerates have been tentatively grouped with the Kanieri series, but the area within which they occur has been indicated on the maps by a broken line.

The area within the aureole of contact metamorphism is an interesting one, as a gradual transition from comparatively unaltered rocks to mica-schists is well exhibited within comparatively narrow limits. The best natural sections showing the transitions referred to are afforded by the small creeks which enter Kanieri Lake on its eastern shore from the flanks of Mount Tuhua. Most conspicuous here is the gradually increasing size of the biotite plates in the metamorphic rocks as the Tuhua intrusives are approached, while near the actual contact compact biotite-schists are found. At the south end of the lake, both on its eastern and western shores, the schists assume a massive appearance, and weather deeply to a greyish argillaceous product. At the Cave, which is situated in the vicinity of the contact with the Tuhua formation on the western shore, calcareous crusts and stalactites are deposited by surface water, leaching out the secondary carbonates along this plane of weakness. The shores of the Milltown Reservoir exhibit the most highly metamorphosed rocks of the series—compact biotite-schists—although the actual position of the contact with the Tuhua granitic formation is not visible.

*To accompany report on the Hokitika Sheet of the North Westland Quadrangle.*



Section along Line A B, Kanieri & Mahinapua Survey Districts

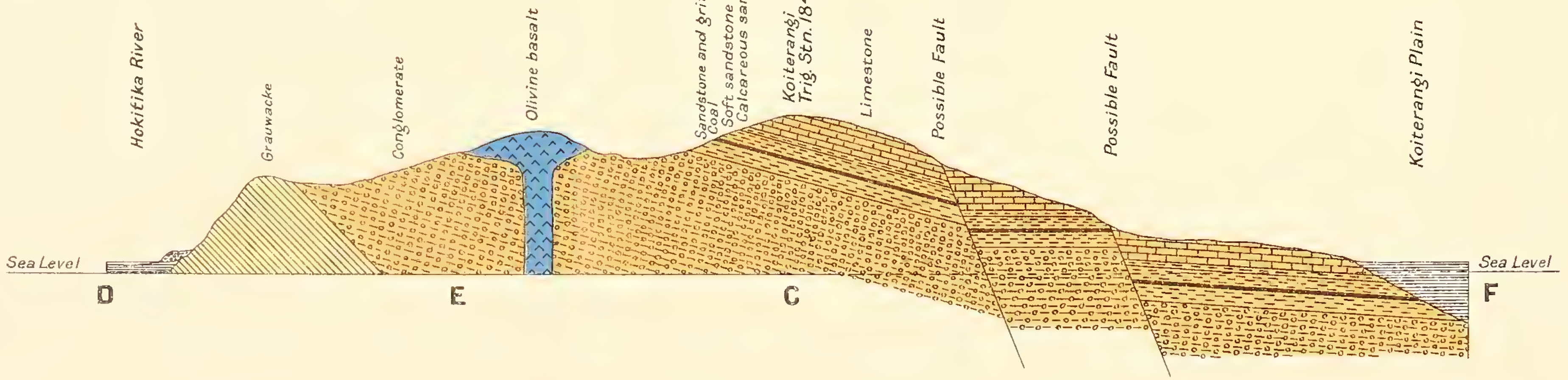
—Scales—

Horizontal
80 60 40 20 0 80 160
CHAINS

Vertical
1000 0 1000 2000 3000 4000
FEET

N.Z. GEOLOGICAL SURVEY

JAMES MACKINTOSH BELL
Director



Section along Line DECF, Kanieri & Mahinapua S.D.'s

— Natural Scale —
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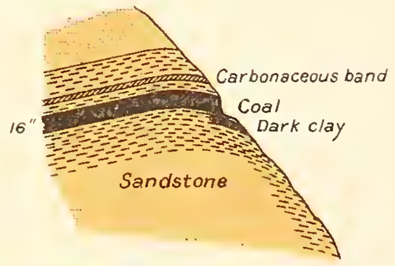
CHAINS



Section through Coal Seam at K, Kanieri S.D.

Approximate Scale
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FEET

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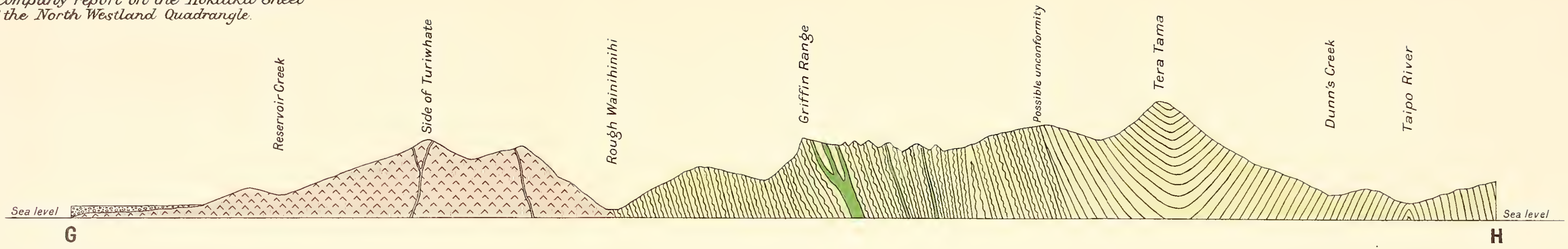
*To accompany report on the Hokitika Sheet of the North Westland Quadrangle.*



Section along Line G H, Turiwhate Survey District

Natural Scale

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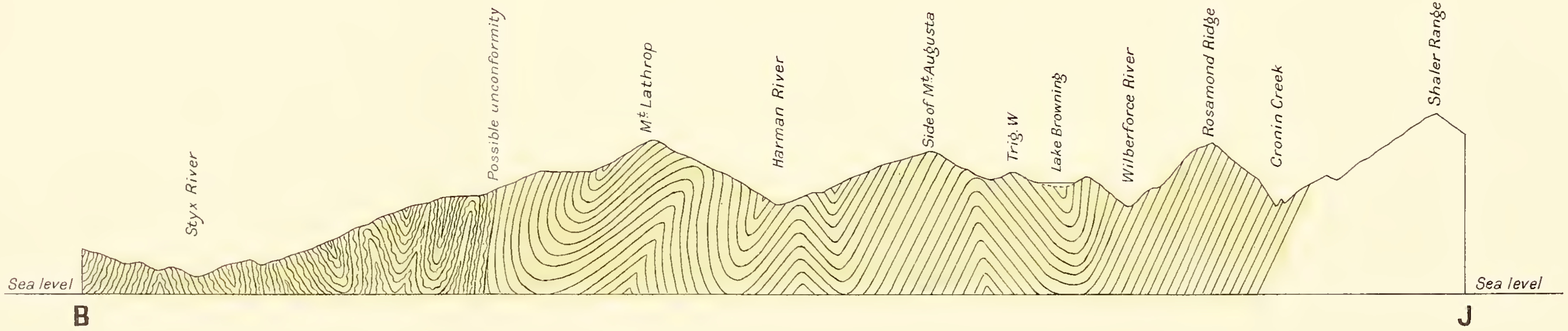
0 2000 4000 6000 FEET

N.Z. GEOLOGICAL SURVEY

JAMES MACKINTOSH BELL
Director



Section along Line B J, Browning's Pass Survey District

Natural Scale

80 60 40 20 0 CHAINS 80 160

0 2000 4000 6000 FEET

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# CHAPTER VI.

## QUARTZ VEINS OF THE ARAHURA AND KANIERI SERIES.

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### General Distribution of the Veins of the Arahura Series.

The schistose rocks of the western portion of the Arahura series appear to be in the main singularly devoid of quartz veins of any persistence or definition. The occurrence of quartz is confined chiefly to thread-like veinlets, with occasionally larger lenticular sheets, running through the schists parallel to the planes of foliation. The principal exceptions to this generalisation are furnished by certain more or less definite veins occurring in the vicinity of the Tuhua formation at the western limits of the series, and also by another group, the genesis of which from their position and character must be connected with the intrusive rocks of the Pounamu formation.

In the eastern or comparatively unaltered rocks of the Arahura series quartz veins have a fairly wide distribution, but the investigations of the writers suggest that probably only those occurring in a more or less well-defined belt have economic potentialities. The limits and extent of the belt referred to will be suggested by a consideration of the vein occurrences here described in detail, but it may be said to be bordered on the westward by an arbitrary line extending from the point where the eastern boundary of the Turiwhate district crosses the Teremakau River, in a general direction of south 35° west, through the upper part of the third gorge of the Arahura to the western boundary of the Browning's Pass district, some two miles and a half north of its south-west corner. The maximum width of the area in which the veins occur is about five miles, as judged by its extension in the area considered in this report, and by the known occurrences of auriferous veins lying to the eastward of that area.

### *(a.) Quartz Veins near the Western Limits of the Arahura Series.*

*Styx River Reef.*—On the northern bank of the Styx River, about 25 chains below the junction of Camp Creek, a quartz-vein formation was located striking north 36° east, and dipping to the westward at an angle of 65°. The quartz is disposed as several bands divided by layers of the country rock, the best defined of these bands attaining a width of 2 ft. It is fairly favourable in appearance, contains a small percentage of pyrites, and occasionally micaceous minerals, and is enclosed in a quartz-mica schist. A tunnel has been driven for some 25 ft., and in this the reef was intersected. It is therefore probable the vein may have at some point indicated its auriferous character, but tests carried out by officers of the Geological Survey on the quartz exposed failed to determine the presence of gold.

*Lynch's Creek Reef.*—A short distance below the high cascades on Lynch's Creek a lode formation exists striking north 26° east, and cutting the enclosing rocks—mica schists—at an acute angle. The formation consists of a narrow band of quartz a few inches wide on the hanging-wall side, with 2 ft. to 3 ft. of a mixture of quartz and dark ferruginous material extending to the hanging-wall. A small percentage of pyrite and chalcopyrite is present, though there is apparently no gold.

### (b.) *Quartz Veins occurring in the Vicinity of the Pounamu Intrusives.*

*Taipo Gorge Reef.*—Outcropping in the Taipo Gorge on its left side and some 8 chains below the junction of Rocky Creek is a quartz vein which attains a maximum width of about 1 ft. It is a bedded vein standing approximately vertical, striking north 13° east, and enclosed in banded schists. A highly quartzose mica schist forms its eastern side and a more finely laminated biotite schist its western wall, while the quartz of the vein itself at times shades into what is almost a quartz schist. It is apparently lenzoid both in its horizontal and vertical extension, contains a small percentage of pyrite and chalcopyrite, and is in places stained with rusty ferruginous matter. This reef is of interest chiefly on account of its platinum content. The following is the result of an assay of a sample from this reef: Platinum, 1 dwt. per ton; silver, 6 dwt. 13 gr. per ton. This sample contained no gold.

*Harley's Creek Reef.*—In the bed of Harley's Creek and about half a mile southward from the Christchurch Road the country rock consists of a dark shaly phyllite, striking north 36° east, and dipping south-eastward about 55°. Intercalated with these rocks are numerous veins of quartz of small dimensions and lenticular both in vertical and horizontal extension. The quartz is white, semi-vitreous, considerably jointed, and is stained with ferruginous matter. The analysis of two samples resulted as follows: No. 1—Platinum 3 dwt. 8 gr., and silver 1 oz. 4 dwt. 9 gr., per ton; No. 2—Platinum 1 dwt. 2 gr., and silver 7 dwt. 13 gr., per ton.

The discovery of platinum in the quartz of the Taipo Gorge vein and of Harley's Creek is of considerable interest and may prove valuable. Apparently the only other instance of its having been detected in quartz in New Zealand is that recorded by Mr. J. A. Pond, in "Transactions of the New Zealand Institute."* The platiniferous quartz here referred to was obtained from the Queen of Beauty Shaft, Thames, at a depth of 540 ft. to 600 ft., and, although the examination was only a qualitative one, gold, silver, and iridium were also isolated.

The physical condition of the metals in the quartz of Taipo Gorge and Harley's Creek has not yet been determined, as the original samples were of rather small bulk. A comparison of the three assays from different occurrences, however, is interesting, as in no case is there a trace of gold present, while silver invariably accompanies the platinum in a fairly uniform ratio of about seven to one.

*Olderog's Reef.*—On the steep precipitous faces which mark the southern termination of McArthur Crags, overlooking the Arahura River, a bedded quartz vein not less than 4 ft. in width is exposed in a rather inaccessible position. This reef is in the vicinity of the massive Pounamu intrusives, which appear so prominently in this part of the area. The quartz is banded in places, heavily mineralised, and on the surface sometimes exhibits a blackish and brownish coating of iron and manganese oxides. Specimens taken for analysis give a negative result for gold, silver, and platinum.

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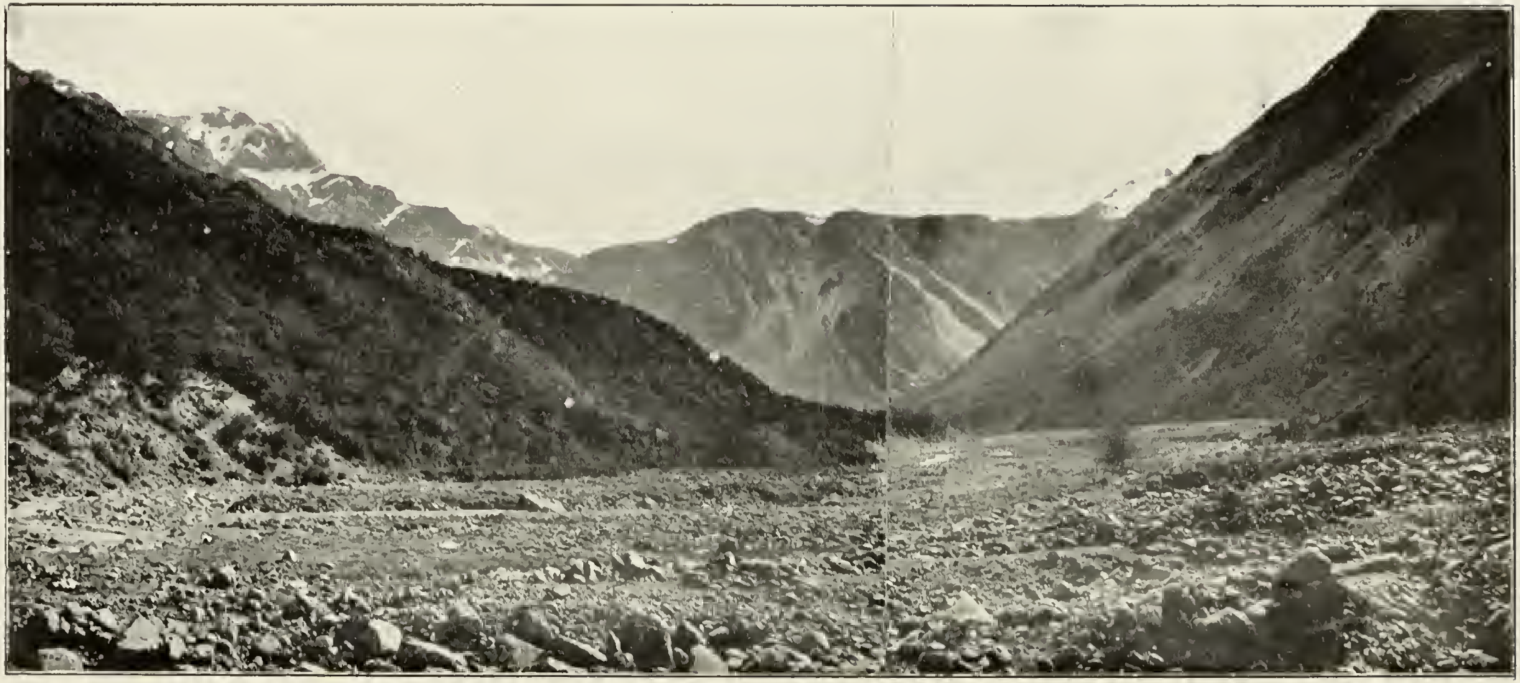
* Vol. xv, 1882.



Browning's Pass, showing Twin Peaks and Mount Harman, from Bed of Upper Wilberforce River.

*Geological Bulletin.*]

*The Golden Crescent Reef.*—On the crest of the Griffin Range, at a point indicated on the map accompanying this bulletin, and in close proximity to the Pounamu formation, a lenticular quartz vein was located, but analyses of samples indicated a gold-content of only 2 gr. per ton. The width is at least 3 ft., and is traceable for over 100 ft. beneath the tussock.

### *(c.) Quartz Veins of the Upper Arahura Series.*

#### (1.) *History of the Westland Reefs.*

As the Westland or Wilberforce reefs area is at the present time attracting some attention, the following historical notes gleaned from the present prospectors are submitted:—

Wilson's Reward reef was discovered in the year 1882 by Mr. Charles Stuart MacGregor, a West Coast prospector, who traced to their origin certain fragments of auriferous quartz found in the headwaters of the Wilberforce River. As the result of this discovery a prospecting syndicate was formed in Christchurch to exploit the find, and a parcel of 3 tons of ore was selected, sent to Auckland, and there treated, giving, it is said, a result of 13 oz. of gold to the ton. Some time after a claim was surveyed, the title granted, and the Wilberforce Gold-mining Company was formed to develop the property. In 1885 a low-level tunnel (the entrance to which is now covered by talus *débris*) was driven by this company from near the base of the Wilberforce Valley to intersect the reef prospected on the mountain slopes. It is stated that although this tunnel attained a length of some 1,000 ft., the Wilson's Reward reef, owing to its westerly underlie, was not reached; but at about 600 ft. from the entrance of the tunnel another reef 4 ft. wide was intersected, from which tests of quartz yielded 12 dwt. per ton by the ordinary battery and amalgamation process. Mining operations were afterwards suspended, and the company eventually went into liquidation.

Not until December, 1902, did this property again receive attention. About this time Mr. James Darward, of Christchurch, one of the shareholders in the original company, accompanied by Mr. Robert Hyndman, of Reefton, further prospected the outcrops, but on account of severe weather little was done until the following summer (January, 1904), when Messrs. Melville Grey and R. Hyndman took away samples for assay. These assays proved satisfactory, and parcel of half a ton was sent to Reefton, and on treatment yielded, it is said, 1 oz. 9 dwt. 21 gr. of gold. In November of the same year the tunnel referred to later in this report was commenced by Messrs. Hyndman and Cameron, acting for the present prospectors, and further surface prospecting has been carried on intermittently up to the present time.

Since June, 1904, other areas in the district in addition to the Wilson's Reward claim have received attention, and numerous quartz veins, some of them auriferous, have been located and prospected to a certain extent along their line of outcrop. These will be fully dealt with in the subsequent pages.

#### (2.) *Wilson's Reward Reef.*

Wilson's Reward reef is situated at an elevation of 5,330 ft. on the south-eastern slopes of Mount Harman, or 900 ft. above the bed of the main headwater branch of the Wilberforce River, which here descends from Pope's Pass and skirts the base of the mountain.

Interstratified argillites and grauwackes, the former predominating, constitute the country rock. The slopes are steep and devoid of vegetation, while the shattered nature of the rocks *in situ* and the numerous steep talus slopes afford pointed evidence of an exceedingly rapid rate of denudation.

An examination of the surface shows quartz outcrops of considerable dimensions, and, as far as could be seen, they cover a lineal extent of approximately 150 ft., but concealed beneath surface *débris* they may continue to greater distances. These outcrops, however, do not occur in very definite alignment, and are suggestive of a mineralised zone rather than of a definite vein. The strike in general corresponds to that of the strata—viz., north 5° east—while the inclination of the dip is to the westward at angles varying from 40° to 60°. The quartz occurs in this zone as large lens-shaped masses, which weaken in the direction of the strike, die out, and are replaced by similar lenses, and, as may be expected, areas exist in which little or no quartz, or only isolated bunches, are found. The maximum width of the best-defined surface outcrops is not less than 21 ft., but normally the vein-material is much narrower. Slaty shales or argillites form the enclosing rocks, and irregular fragments, sheet-like masses, and thin partings of this material are frequently included within the quartz.

At a vertical height of 100 ft. below the outcrops a tunnel 170 ft. in length, coursing due north, has been driven through the country rock to the east of the reef, which was met with at a very acute angle on the foot-wall side. At this point a crosscut has been put in, which, judging by information afforded by surface outcrops, is transverse to the strike of the reef. Some 13 ft. 8 in. of quartz has been cut through without exposing the hanging-wall, and at this point operations were suspended. The argillites forming the country rock in the tunnel preserve the same strike and dip as at the surface, but are much slickensided, and show throughout indications of minor faulting. As regards the continuity of the reef at this level the very limited extent of the workings precludes anything definite being said, but it is at least apparent that a considerable body of quartz exists.

The vein-material consists of quartz of a milk-white and sometimes semi-vitreous appearance, with occasional drusy cavites. Although sometimes massive, it is in the main closely jointed in such directions as to cause it to yield on fracture numerous small cuboidal or rhomboidal fragments, giving it in places the appearance of being pseudomorphous after calcite. Generally the jointing must be attributed to the various dynamic stresses which have accompanied movements in the enclosing rocks. The most conspicuous feature of the vein-material is the inclusion of irregular-shaped fragments of argillite as well as thin partings of the same material. The black and often shining argillite cemented in the white quartz presents a marked contrast, and this variety is termed by the miners "magpie" ore. The vein-material contains a small percentage of sulphides, chiefly pyrite and chalcopyrite, and naturally these are of more frequent occurrence at the tunnel level than at the surface. Rusty streaks of iron-oxides and occasional malachite stains coating the joint planes and the slaty partings are characteristic of both the surface outcrops and the quartz in the tunnel, and are due to the leaching of the products of decomposition of the sulphides. Gold is occasionally visible in the vein-material, more particularly in association with the inclusions—slickensided partings and selvages of argillite.

The results of assays of samples taken from the outcrops and from the tunnel level are as follows:—

| | Gold. | | | Silver. | | | Value per Ton. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Oz. | dwt. | gr. | Oz. | dwt. | gr. | £ | s. | d. |
| (1.) General sample of quartz selected from various outcrops ... ... ... ... | 0 | 0 | 16 | | ... | | 0 | 2 | 8 |
| (2.) General sample selected in tunnel level from a width of 13 ft. 8 in. of reef ... ... .. | 0 | 0 | 4·5 | | .. | | 0 | 0 | 9 |
| (3.) Sample from bunch of high-grade ore in reef showing a little gold ... ... ... ... ... | 3 | 5 | 10 | 0 | 8 | 4 | 13 | 2 | 6 |
| (4.) Sample taken from an outcrop on surface (21 ft. wide), but not representative of the whole ... | 0 | 13 | 0 | 0 | 3 | 5 | 2 | 12 | 8 |

Note.—The gold and silver in the litharge used in these assays has been carefully determined and deducted in each case.

The above results tend to show that the ore *en masse* as at present exposed is of low grade, but that it includes bunches carrying high values.

It is generally acknowledged that the sampling for assay purposes of such ore-bodies, with the object of arriving at their average value, or even the value of certain definite workable portions, is extremely difficult if not altogether impossible. Only by careful selection of bulk parcels and the treatment of these by suitable milling methods can the commercial value of the vein formation be arrived at.

### (3.) *Reefs of Mount Harman other than Wilson's Reward.*

*Kanieri Syndicate's Reefs.*—Two quartz reefs (known as the Kanieri syndicate's reefs) have been located on the eastern slopes of Mount Harman, facing Pope's Pass, at an elevation of 5,540 ft. The most northerly outcrop of the lower of these reefs constitutes all that was visible above the snow at the time of examination. This reef here averages 6 in. in width, and is conformable with the stratification of the argillites and grauwackes which strike north 4° east, and dip westerly at an angle of 41°. Further south that the portion exposed this reef is stated to average 15 in. in width over a lineal extent of 400 ft., and to give gold on crushing and panning, though the analysis of samples from the only available outcrop showed no trace of gold. The quartz is white, semi-vitreous, often ferruginously stained and "rubbly."

*Hyndman's Reef.*—Hyndman's reef, on the south-western slope of Mount Harman, where observed, has a width of 3 ft., but the outcrops on its northerly trend, covered with snow at the time of visit, are said to exceed this measurement. The quartz occurs in a definite bedded vein striking north 6° east, and dipping at 80° to the westward. It can be traced for 15 ft. along the high cliff facing the Upper Wilberforce. It is overlain by blackish, broken argillite and underlain by hard grauwacke. The quartz is whitish opaque and often rusty. It proved barren on analysis. Near the eastern base of Mount Harman, and a few hundred feet above the Wilberforce River bed, a small irregular bedded and faulted vein occurs in grauwacke and slaty argillites. An analysis of this quartz showed no gold.

Connected with the area in the immediate vicinity of Browning's Pass may be mentioned two veins of minor importance occurring in O'Connor's Creek, Upper Arahura. Assays showed a gold content in the one case of 1 gr. of gold per ton, and in the other of 16 gr. of gold per ton.

### (4.) *Reefs of Billet's Prospecting Area.*

*Grave Creek Reef.*—This is situated some 45 chains up Grave Creek on its northern side, and is exposed for some 70 ft., preserving a general strike of north 12° east, and dipping westerly at angles averaging 42°. The elevation of the reef above the Wilberforce River at the junction of Grave Creek is 540 ft. This must be regarded as a mineralised zone rather than a definite vein, and appears to have no extension south of Grave Creek. The maximum width of actual quartz exposed is at the most southerly point of outcrop where it measures 5 ft., while northwards several narrow lenticular bands alone represent the formation. The vein-material on the whole resembles that of other reef occurrences in this area, but is less promising in character, and no gold could be detected by crushing and panning, nor did a fair sample on assay show a trace of the precious metals.

*Billet's Reef.*—On the steep broken slopes forming the southern flanks of Marshall Ridge, and at an elevation of 1,510 ft. above the junction of Hall Creek and the Wilberforce River, very irregular though fairly large outcrops of quartz exist. In places these large lenticular masses are almost conformable with the bedding, and again cut it at almost right angles. On the whole the quartz formation lacks definition, and the samples selected from it did not prove auriferous.

A short distance to the south of Hyndman's Creek, and at an elevation of 1,228 ft. above the junction of the Wilberforce River and Hall Creek, quartz is exposed in a small surface excavation on a grassy knoll. 2 ft. of quartz is here visible, but neither the strike nor dip of the vein formation can be determined. In addition to pyrite, chalcopyrite and its decomposition product malachite are noticeable. Fair prospects are said to have been obtained by crushing and panning, but the samples taken for analysis proved barren.

### (5.) *Reefs of Fiddes and Baucke's Area.*

*Fiddes's Reward Reef* traverses the western slopes of the main Upper Wilberforce Valley, and has been traced southward from Grave Creek to the razorbacked ridge which, striking transversely to the main valley, connects Reese's Peak with the Emperor's Knob. The reef is distant some 77 chains from the bottom of the Wilberforce Valley, *via* Grave Creek, and the elevation of the outcrops here averages 1,510 ft. above the main river-bed. On its southern trend it crosses Spencer's Creek, a small right-hand branch of Grave Creek, and beyond this has been located on the sharp ridge already mentioned at an elevation of 2,068 ft. above the river-bed. From the most northerly to the most southerly outcrop the distance measures about 30 chains. The average strike varies little from due north and south, and the dip is westward at about 55°.

Argillites and grauwackes are the enclosing rocks, and the vein is either conformable to the bedding planes of these or cuts them at acute angles. Its surface extension has been proved for a greater distance than that of any of the other reefs in the whole area, but it must not be inferred that the exposed outcrops are continuous, since a great deal of the area along the strike is covered with rock talus, and in places the formation itself lenses out. In width this vein attains a maximum of 2 ft. to 3 ft., but probably 6 in. would represent its average dimensions.

The quartz in the main resembles that of the district generally, but is usually characterized by the iron-oxides occurring as very finely disseminated material in nests or cavities as well as forming iron stainings in the joint planes. Pyrite and chalcopyrite constitute the predominent sulphides. Fine gold is occasionally visible in the vein-stuff at various outcrops along its whole trend; this gold is in the main associated with the slaty inclusions, partings, and selvages, but also occurs throughout the mass of the quartz in conjunction with the sulphides, and with the finely divided iron-oxides derived from the sulphides. The most promising sections of the vein formation yet exposed are located over a linear extent of 300 ft. southward of a point which is about 10 chains south of Grave Creek. Here the vein-material bears a promising appearance, and free gold is frequently visible, or may be obtained by panning the disintegrated vein-material and rusty, slaty selvages. Solid quartz, subjected to the ordinary crushing and concentration test, confirms the occurrence of gold in the main mass of the quartz. On its southern trend towards the razorback ridge, talus *débris* covers the surface and often conceals the reef. Where exposed the vein is often fairly well defined and maintains its characteristics, though frequently small parallel stringers and lenses of quartz accompanied by mullocky argillite alone represent the vein formation.

The results of assays of the vein-material are as under:—

| | Gold. | | | Silver. | | | Value. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Oz. | dwt. | gr. | Oz. | dwt. | gr. | £ | s. | d. |
| (1.) Northern portion: General sample of quartz, showing no visible gold ... ... ... ... | 0 | 3 | 1 | 0 | 0 | 10 | 0 | 12 | 2 |
| (2.) Northern portion: Specimen quartz ... ... | 10 | 4 | 4 | 0 | 15 | 15 | 40 | 18 | 2 |
| (3.) Southern portion: High-grade selected ore, showing gold ... ... ... ... ... | 4 | 7 | 17 | 0 | 8 | 1 | 17 | 11 | 7 |

*Fiddes's Stringer Reefs.*—About 8 chains above the junction of Spencer Creek with Grave Creek a vein appears at the south-eastern edge of the hard snow which fills the creek-bed. It has a maximum width of 5 ft. 6 in., but narrows vertically in the steep slope of argillites in which it is located. The quartz is much mixed with mullock, and is often rusty. To the southward of the outcrop in the creek the reef dies out at a comparatively short distance. Quartz from this reef on crushing and panning is said to show gold. Stringers of quartz in soft mullocky argillite appear a few chains to the eastward of Fiddes's Reward reef. They are brokenly continuous from the point just vertically above the mouth of Spencer's Creek for some chains along the strike. A sample from these stringers showed a gold-content at the rate of 1 dwt. 5 gr. per ton.

From the above results it will be seen that the same remarks apply to these reefs as to Wilson's Reward as regards forming a reliable estimate of their commercial value. It can, however, be here stated that the results and indications afforded by Fiddes's Reward reef warrant the area enclosing it being regarded as a promising prospecting proposition.

### (6.) *Kanieri Syndicate's Area.*

*Pfhulert's Reef.*—The course of this reef crosses Snowy Creek at an elevation of 1,530 ft. above its junction with the Wilberforce River. In the steep rock faces which here rise on the southern side of the creek only stringers and bunches of quartz indicate the track of the reef, and from appearances its northern continuation from this point is not worthy of consideration. Southward, however, from the steep rock face the reef has been exposed by trenching and transverse surface cuts for a distance of about 250 ft., and the presence of small isolated outcrops of quartz amid the rock talus for some 2 or 3 chains beyond this suggests its further extension. The elevation of these outcrops is 4,640 ft., or 1,740 ft. above the Wilberforce River. The strike of the vein averages north 19° west, and the dip 40° to 50° to the westward. The average width of the vein-material is 30 in. as calculated from six different cross-sections, and on the assumption that the reef where not exposed between these cuts varies regularly. 5 ft. of solid quartz is exposed where the reef attains its maximum width. The quartz throughout is of a favourable character, and, like that of many of the other veins of the district, is traversed by numerous joint planes both parallel and transverse to the enclosing walls, and these cause the vein-quartz to break usually into rhomboidal fragments. Slaty selvages and partings and small inclusions of argillaceous rocks are common throughout the quartz which is mineralised with pyrite, chalcopyrite, and specular iron, and the decomposition products of these minerals—iron-oxides and copper-carbonates. Gold was seen at frequent intervals throughout the full length of the better defined portions of the outcrop, generally associated with the rusty slaty selvages and partings, but occasionally in the solid quartz.

A general sample selected from various points along the full length of the outcrop yielded on assay: Gold, 1 dwt. 5 gr. per ton; silver. 5 gr. per ton: value, 4s. 10d. It may be remarked that in the above sample no gold was seen. Again, other fragments of quartz showing a little gold yielded on assay: Gold, 8 oz. 9 dwt. 21 gr. per ton: value, £33 19s. 6d. Silver, 1 oz. 1 dwt. 4 gr. per ton: value, 2s. 1d. Total value, £34 1s. 7d.

As will be inferred from the above neither of these results can be regarded as representative, and it must be stated that no mere surface examination, although supported by assays, will finally prove the value of this or any vein of a similar nature. However, after a careful examination the writers may be warranted in asserting that this vein, which gives evidence of continuity at least in linear extent, which shows fair prospects of gold at several points along its outcrop, and which also traverses a favourable class of rock, may be regarded as a fair prospecting proposition.

### (7.) *Reefs of Other Leases.*

In Morris's lease irregular bedded quartz veins have been located on the ridge connecting Reese's Peak with Emperor's Knob, and also on the north side of Specimen Creek, a short distance above its junction with the main river. Little or no prospecting has been done on these veins, nor did the samples taken for analysis prove auriferous.

In Hutchinson's lease veins similar to those just described occur on this same ridge, but on the south side of Specimen Creek a small, rather irregular vein carries a little visible gold on its slaty selvages.

### (8.) *Taipo Reefs.*

*Taipo Corner Reef.*—At Taipo Corner, which is situated on the left bank of the Taipo River some 70 chains above the Scotty's Creek junction, a comparatively recent slip has exposed a quartz reef of some dimensions. This bedded vein, which preserves a general strike of north 34° east, and dips at 70° to the north-westward, traverses slightly schistose grauwackes and blackish phyllites, and is exposed for a linear extent of 120 ft. At its most westerly exposure, 50 ft. above the river-level, the total width of the reef formation is about 9 ft., but of this some 4 ft. consist of slaty partings. On its north-easterly course, 80 ft. above the river-bed, it lenses out, and the quartz aggregates not more than 1 ft. in all.

The vein-quartz is white, somewhat vitreous, considerably jointed, and includes here and there large and fairly well-formed crystals. In the hard freshly fractured quartz pyrite occurs, but over the greater portion of the outcrop all the pyrite has been oxidized, and bright ochreous iron-oxides in a very finely divided state fill small nests throughout the vein-quartz and permeate the slaty selvages. Dishes of the disintegrated decomposed vein-stuff and slaty partings were carefully washed, and all gave a "prospect" of gold mostly in a fine state of division. Likewise freshly broken quartz containing nests of fine iron-oxides on crushing and panning yielded a little gold. As against the above concentration tests, a sample selected for assay returned only—Gold, 22 gr. per ton; silver, nil: value, 3s. 8d.

From these results the only conclusion that can be arrived at is that the gold is not evenly disseminated throughout the vein-stuff, and only by the testing of bulk parcels can the actual value be ascertained. That this fairly large vein should yield encouraging "prospects" at its only observed point of outcrop may warrant its being further exploited, as its position renders it easily accessible at all seasons of the year.

*Freitas Creek Reefs.*—Freitas Creek, at a distance of from a mile to a mile and a half above its junction with the Taipo River, cuts through and exposes several zones of grauwacke and argillite, which are highly mineralised, containing abundant finely disseminated iron-pyrites and numerous parallel quartz stringers and quartzose bands. Oxidized portions containing throughout abundant rusty ferruginous matter are conspicuous. Some of the mineralised zones are not less than 16 ft wide, but, although gold could be got by panning the creek gravels below all of these occurrences, traces of gold and silver were detected on analysis in only one of them, while in none could a "colour" be obtained by pounding and washing samples from various points. The general appearance of these, however, is so favourable that they might with advantage be traced and prospected along their line of strike.

*Low's Creek Reef.*—In Low's Creek, a left-hand branch of Dunn's Creek, a mineralised zone of about 25 ft. in width is exposed in the creek-bed about a mile from the junction. This is probably a northerly continuation of one of the zones occurring in Freitas Creek. It consists of ferruginously stained argillites and grauwackes, often partially silicified. Assays for gold and silver from this zone gave negative results, and crushing and washing operations failed to show a "colour."

*Dunn's Creek Reefs.*—About a mile and a quarter above the mouth of Dunn's Creek narrow quartz veins appear on a high slip on the northern side of the stream, about 300 ft. above the stream-bed. They are of no value.

*Scotty's Creek Reefs.*—Numerous lenticular quartz veins were located in the valley of Scotty's Creek, although nothing of note was discovered. The finding of highly auriferous quartz fragments in this creek-bed has been reported from time to time, and it is possible that concealed beneath the vegetation and surface *débris* the vein or veins may exist which contributed this quartz to the creek detritus.

*Hura Creek Reefs.*—The lowest part of Hura Saddle, which separates the headwaters of McQuilkin Creek from those of Hura Creek, is in the main covered by surface loam and tussock grasses. In one of the streamlets, rising on Hura Saddle, which falls to the Hura Creek valley, and at a point some 370 ft. below the crest of the saddle, a fragment of quartz about 5 lb. in weight was discovered, which on one face included a beaten-out ragged streak of gold in the aggregate amounting to at least ½ dwt. The quartz bears a striking resemblance to the auriferous quartz of Gold Creek, which will be described later. The discovery of this auriferous quartz is important, and, as it occurs so near the cap of the dividing range, the location of the vein by trenching and surface prospecting should not be a difficult matter, and might be undertaken with advantage. Several small stringers of quartz appear on Hura Creek at intervals for half a mile below the saddle, but are unimportant.

*Gold Creek Reef.*—Gold Creek joins the left-hand branch of the Taipo River, or Julia Creek, on its north-western side, about 75 chains above its junction with Mary Creek. In the actual bed of Gold Creek, and about seventy-five paces from its mouth, a bedded reef formation was located. This consists of narrow alternating bands of grauwacke-slate and vein-quartz striking north 60° east, and dipping at high angles to the eastward. This formation is exposed for a width of about 3 ft. from the foot-wall, but the hanging-wall portion is covered by heavy creek *débris*, so that its actual width is unknown. As to linear extent the quartz bands of the formation appear to have little or no continuity north of the creek-bed, whereas to the south heavy talus *débris* covers everything just where further investigation would be of value. The visible outcrop is only some 5 ft. to 6 ft. in length. The quartz is of a very favourable character, showing numerous small angular slaty inclusions and pyrite throughout. One of the small quartz bands which streak the formation is highly auriferous, and where widest (4 in.) every fragment of the quartz broken out showed coarse gold. This gold appears to have an intimate connection with pyrite, and is found throughout the solid quartz rather than, as is often the case in other veins of the area, on the slaty selvages. Other very small quartzose ribs contain gold to a lesser extent, and some of these intersect the banded formation more or less transversely. The quartz bands form only a minor proportion of the whole formation, although silicification is to some extent evident throughout.

A sample selected from various parts of the formation which showed no gold assayed—Gold, 1 dwt. 14 gr. per ton; value, 6s. 4d. Two other samples of ore, out of which everything showing gold was selected and discarded, resulted—Gold, 1 dwt. 16 gr. per ton; value, 6s. 8d.: and gold, 1 dwt. 6 gr. per ton; value, 5s. An assay of a sample of ore broken from the auriferous-quartz band resulted as follows: Gold, 5 oz. 3 dwt. 8 gr. per ton; value, £20 13s. 4d.: silver, 17 dwt. 15 gr. per ton; value, 1s. 7d.: total value, £20 14s. 11d.

This reef formation should warrant further investigation in a southerly direction below the talus *débris*, as the quartz bands in this direction show indications of increasing in width, and, judging by the results already obtained in connection with this reef, where such enlargement takes place the ore improves in value.

### (9.) *McQuilkin's Creek Reefs.*

One of the best defined quartz veins of the Arahura series is to be found within the watershed of McQuilkin's Creek, a tributary of the Arahura River. The distance of this occurrence from the main river is only about a mile and a quarter, and the elevation above the river-bed 1,300 ft., but it is difficult of access, as travelling is rendered very slow and tedious owing to the roughness of the creek-bed. The reef is exposed in a small stream coming in on the northern side, but it is distant only about 5 chains, and is actually visible from the main creek. The vein strikes north 22° east, dips westward at about 65°, and is enclosed in a grauwacke slate, which in places bears a faint silky lustre. It is in some places apparently conformable with the bedding, and in others cuts the stratification at very acute angles. The quartz outcrop is exposed for a distance of 100 ft., and varies from 15 in. to 30 in. in thickness. The vein-quartz is of a white semi-vitreous appearance, and throughout it isolated aggregates of pyrite, chalcopyrite, bornite, and specular iron occur. The weathering products of the sulphides are leached along the numerous jointing planes of the quartz, iron-oxide stains with crusts and coatings of malachite being conspicuous. Where the vein is solid and compact slaty inclusions are not very common, but thin selvages of slickensided slaty material separate the actual quartz from the enclosing wall rocks.

The only gold that was seen in this vein occurred as a coarse bleb in the quartz in the vicinity of one of these selvages. The analysis of a general sample showed a gold-content of 1·5 gr. per ton.

As auriferous quartz occurs in the *débris* of McQuilkin's Creek, and also free coarse gold very little water-worn, the reef just described should warrant further investigation. Fragments of quartz of a very favourable description also occur a few chains higher up in the creek-bed than the outcrop of the reef just described. These are shed from the slopes on the northern side of the creek, and indicate the presence of another reef.

## QUARTZ VEINS OF THE KANIERI SERIES.

The extent of the rocks of the Kanieri series is very limited in the area under discussion, but, as will be inferred from the occurrences later described, quartz veins have a very general distribution throughout. It might reasonably be expected that in these rocks, which have been correlated by previous writers with the auriferous series near Reefton, and which have been considerably influenced by the granitic intrusions, auriferous quartz reefs might occur. It will, however, be noticed from the previous chapter that, although interstratified slaty bands do occur here, the great mass of the rock is coarse-grained, and is not of the description usually associated with the auriferous veins of the district. A careful examination was made of all the creek-beds, lake-margins, and water-races presenting rock outcrops, but, although several reefs were located, it is to be regretted that they contain gold and silver only in minute quantities. It is significant, however, that whereas a great many reefs occurring in the Arahura series contain no trace of these metals on analysis, negative results have not been reported from quartz veins of the Kanieri rocks.

The quartz veins of this series are reviewed in their order of occurrence from east to west.

*Milltown.*—Small irregular quartz veinlets outcrop in the massive schists which flank the intrusive granites of Mount Tuhua, and which are exposed in the water-race below the Milltown Reservoir. The quartz yielded no gold on crushing and panning.

*Kanieri Lake.*—A quartz reef (strike and dip obscure) about 2 ft. in width occurs at a point on the westerly margin of the lake, half a mile northward of the "Cave" which marks the granite contact. A good general sample selected from various parts of the reef was subjected to the ordinary dish-and-mortar tests, but failed to yield a colour of gold. Further, it was noted that the vein-stuff contained practically no pyrite or other sulphides.

*Hooker's Creek.*—At a quarter of a mile from the mouth bedded quartz veins of no size were met with.

*Gentle Annie Area.*—Here small irregular bunches and bedded veinlets of quartz of little importance occur, the assays from two different localities being as in (1) and (2) of table appended.

*Bluebottle Stream.*—This stream and its various branches above the crossing of the main Gentle Annie Track disclose several quartz veins. Although fairly coarse gold may be detected in the rock crevices and gravel *débris* over a great part of the watershed, too much significance must not be attached thereto, as glacial material, part of which had an exotic origin, ranges here to a considerable altitude, and certainly to a height of 1,500 ft., in Hooker's Creek, only a few miles to the north of this locality. What may be regarded as the main Bluebottle Stream preserves a fairly straight course from the point where the track reaches it to its source near the granite cliffs, some mile and three-quarters to the south-east. Its four main branches all come in from the rising country to the eastward, and are named as passed in ascending the stream: Lowrie's Creek and Bernard's Creek, the third branch (elevation of junction 800 ft.) and the fourth branch (elevation of junction 860 ft.).

In ascending the main stream only small bedded veinlets of quartz are met with until the junction of the third branch is reached. Here a lensoid quartz vein outcrops with a maximum width of 3 ft., accompanied by lesser branch veinlets, but the vein-stuff, despite this width, is not of a very promising appearance. Some 200 yards above this a similar outcrop or bunch of quartz 4 ft. in lateral dimension appears. A quarter of a mile above the junction of the fourth branch a fairly large bedded vein crosses the creek, enclosed in a slickensided grauwacke, but its appearance is not more favourable than in the case of those already recorded.

At the actual contact of the granite with the sedimentary rock at the head of the stream (1,490 ft), high cliffs, flanked by angular talus and slip material, are prominent. Old miners tell of the existence of a large reef at this point, which was covered by a slip before having been prospected. The occurrence of quartz in the creek *débris* here at least suggests its existence.

*Lowrie's Creek (First Branch).*—At a point (at an elevation of 1,210 ft.) about 600 yards up the stream from the Gentle Annie Track a bedded vein with a strike of north 20° west, dip 45° to east, and width of 3 ft. outcrops. The vein-stuff, which is stained with hæmatite derived from the enclosing rock, carries no pyrite, and is not of a very promising character. A small shaft and other minor excavations are evidences of this reef having been prospected. Analysis No. 4, appended, refers to quartz from this vein.

*Bernard's Creek (Second Branch).*—Some 600 yards up this creek occurs the only true fissure vein observed in the rocks of this series. It ranges from 1 ft. to 3 ft. in width, strikes south 84° east, with a dip to the northward of 45°, and receives numerous cross-veins from the hanging-wall country. The enclosing rock is a micaceous ferruginous grauwacke with well slickensided walls, and while the vein-stuff is in places of a fairly favourable character no gold was detected by crushing and dish concentration (*vide* analysis (5) appended). The value of this vein, however, may change with the class of rock traversed.

*Third and Fourth Branches.*—In the first-named creek at a distance of half a mile from its junction with the main stream, and in the latter-mentioned creek at a distance of one mile above its junction with the main stream at an elevation of 1,480 ft. above sea-level, bedded quartz veins of similar characteristics, ranging in width up to 2 ft. and of practically no value, were located. Analysis No. 3, appended, refers to the vein in the third branch.

*Mulholland's Creek.*—In this creek just above the first outcrop of granite a small quartz vein 10 in. wide showing some iron-oxides was located in the grauwackes involved with the intrusive rock.

The following tabulation sets forth the assays of samples from certain reefs of the Kanieri series which are referred to above:—

| | Gold. | | Silver. | | Value per Ton. | | |
|---|---|---|---|---|---|---|---|
| | Dwt. | gr. | Dwt. | gr. | £ | s. | d. |
| (1.) Butcher Creek | 0 | 5·5 | 3 | 17 | 0 | 1 | 3 |
| (2.) ,, | 0 | 20 | 1 | 15·5 | 0 | 3 | 6 |
| (3.) Bluebottle Stream | 0 | 3·5 | 1 | 9 | 0 | 0 | 9 |
| (4.) ,, | 0 | 3·5 | 1 | 2 | 0 | 0 | 8 |
| (5.) ,, | 0 | 2 | 0 | 11·5 | 0 | 0 | 5 |

Note.—The gold and silver in the litharge used in these assays has been carefully determined and deducted in each case.

## AGE AND ORIGIN OF THE VEINS OF THE ARAHURA AND KANIERI SERIES.

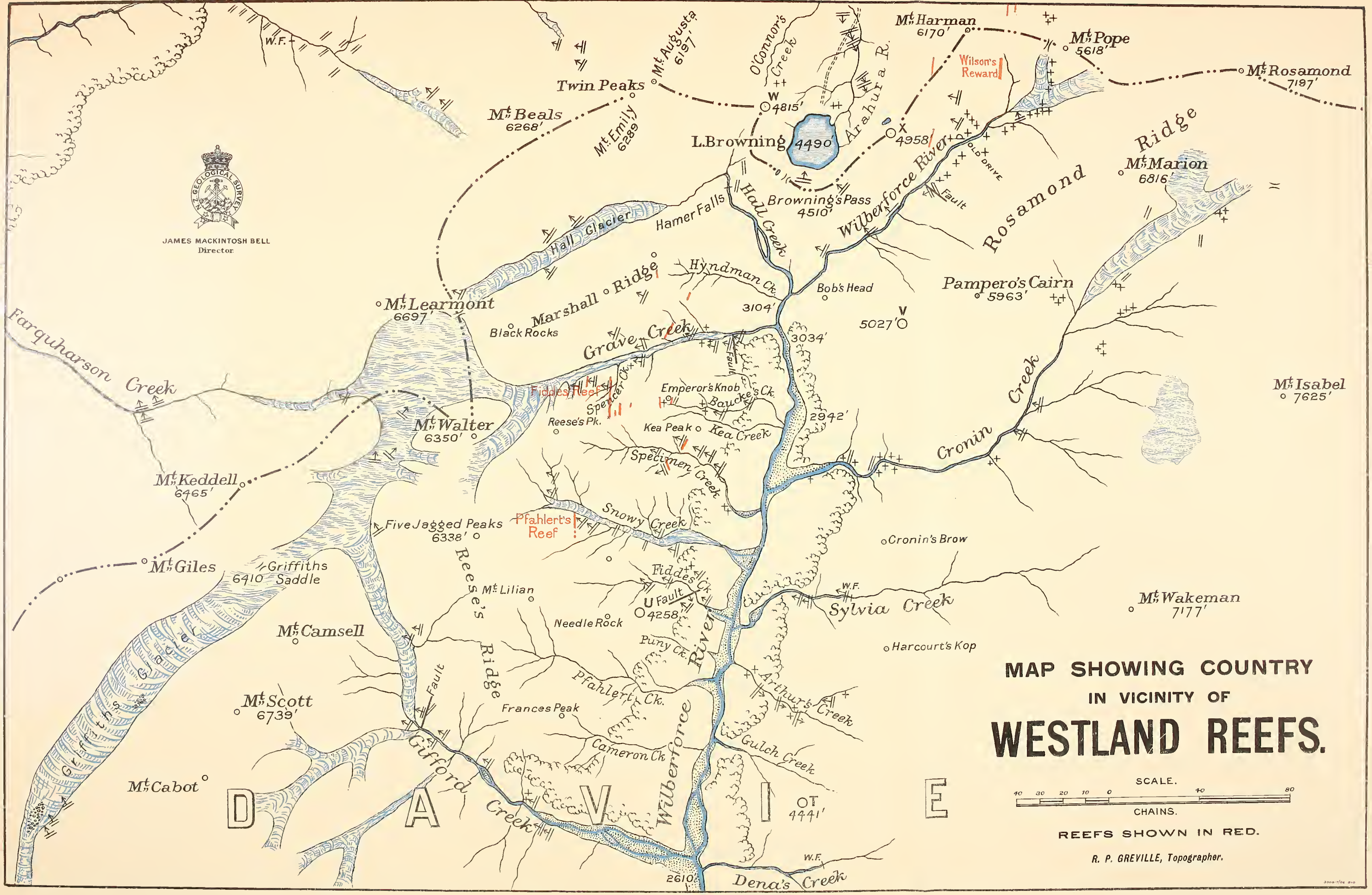
It has already been mentioned that orogenic movements have closely compressed the Arahura and Kanieri strata into numerous longitudinal folds, while the transverse folds are of very minor importance. In consequence the resulting stresses and strains in the rocks appear to have been relieved by the formation of numerous minor fissures parallel to the stratification and schistosity rather than by prominent breaks across the foliation, and lenticular bedded quartz veins rather than true fissure lodes or master veins have resulted. In the whole area examined only one prominent true fissure vein has been located—namely, that in the rocks of the Kanieri series of Bluebottle Creek—the fissuring of the strata in this case evidently having been contemporaneous with the intrusion of the granitic rocks.

The veins of the Kanieri series and the western portion of the Arahura series, and also those in the vicinity of the Pounamu formation, are evidently closely associated with the eruptive " after actions " succeeding the granitic and Pounamu intrusions respectively, but any reliable evidence bearing on the age of the quartz veins of the eastern portion of the Arahura series is not apparent. In the latter case, however, the rudely parallel orientation of the vein-quartz marked by shearing fractures parallel to the slaty structure of the rocks, and also to their minor lateral displacements, indicates a period of formation at least prior to the later movements of the strata. Further, the relatively great amount of quartz occurring in the basal conglomerates of the Koiterangi or Coal series (Cretaceous ?) affords undoubted proof that quartz veins had a very general distribution in the older rocks prior to the formation of these conglomerates.

The comparatively low gold-content of the mass of the quartz in the case of the veins of larger dimensions, and the much more highly auriferous character of the slaty selvages separating the actual quartz from the wall rock in these veins, are characteristic features. The facts are apparently explainable either on the hypothesis that the action of the wall rock has been the most potent factor in the precipitation of the gold from the vein-solutions, or that the main period of auriferous deposition has post-dated the formation of the great mass of the vein-quartz. Although the existence of undoubted secondary quartz which might be expected to accompany this subsequent enrichment is not apparent, certain considerations vaguely suggest the latter hypothesis. The most highly auriferous quartz, ignoring the slaty selvages, which is met with in the area is that occurring in the banded formation of Gold Creek, Taipo River, and again that constituting the loose fragment found near Hura Saddle. These, although widely separated in position, present a marked similarity: the quartz in each case is massive and shows no sign of parallel orientation; further, the contemporaneous deposition of the quartz, the gold, and the sulphides is undoubted. There is a possibility therefore that veins of the Gold Creek type are of later origin than those veins which are highly auriferous only near the slaty selvages, and that their formation may have been contemporaneous with the enrichment of the latter.

There is no evidence of the existence of intrusive rocks in the upper portions of the Arahura series, but within the Hokitika Sheet the presence of basalts of Post-Koiterangi (Cretaceous ?) age is indicative of a period when hydrothermal action may have been renewed, and when a secondary enrichment of some of the veins may have been effected. Further, the existence of hot springs in some of the headwater valleys of the Taipo, Wilberforce, and Kokatahi Rivers emitting $H_2S$ and depositing flocculent silica suggests that vein formation, in certain localities within the area, may be still in progress.

*To accompany report on the Hokitika Sheet of the North Westland Quadrangle.*



# MAP SHOWING COUNTRY IN VICINITY OF

# WESTLAND REEFS.

SCALE.

40 30 20 10 0 40 80

CHAINS.

REEFS SHOWN IN RED.

R. P. GREVILLE, Topographer.

By Authority: John Mackay, Government Printer.

## CHAPTER VII.

## THE TUHUA FORMATION.

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### Content of the Tuhua Rocks.

By far the most extensive group of igneous rocks in North Westland is that included within the Tuhua formation, which consists in the main of a great complex of granites, granitites, and syenites, with every phase of gradation between the three. The rocks of the Tuhua formation intrude those of the Arahura and Kanieri series, and are accordingly of later age. In addition to inclusions of these sedimentary rocks near the contact, the formation has within it small areas of gneiss, which is apparently a metamorphosed rock of greater antiquity than the Tuhua rocks, from which it is sometimes separable with difficulty. On the maps accompanying this report no attempt has been made to demarcate these small sections from the much larger areas of less metamorphosed granite, syenite, &c. Cutting these plutonic rocks and the enclosed gneiss are in places dykes and irregular veins and patches of pegmatite and aplite, which represent the most acid phases of the Tuhua intrusion, and were probably ejected into the intruded rocks while they were still warm. These dyke rocks are considered as practically a part of the Tuhua intrusion, though correctly of slightly later age.

So far as is certainly known the Tuhua rocks were eruptive rather than effusive, though apparently sometimes intruded comparatively near the surface. Certain rocks of doubtful origin in Geologist Creek and just above the gorge of Macpherson's Creek may be true volcanics, though this is not probable.

### Distribution of the Tuhua Formation.

The extension of the Tuhua rocks is considerable within the Hokitika Sheet, the name being given from one of their most typical points of outcrop on Mount Tuhua. On the eastern side of Lake Kanieri the formation shows a belt of variable width, traversing the area under discussion in a general north-easterly direction, while on the western side of the Lake Kanieri a narrow band forms a large boss which starts at the base of Conical Hill, and is probably continuous beyond the limits of the sheet to the south, though in that direction the formation is shrouded by recent fluviatile material. The boundaries of both the wider eastern belt and the minor western band, or Mount Graham boss, are in general fairly regular and uniform in direction, though there are many small irregularities. Towards the contact with the earlier sediments narrow sheets intruded parallel to the stratification are fairly common, though dykes are rare.

Outcrops of the eastern and most prominent belt are conspicuous on the Styx River and along the southern shore of Kanieri Lake, while Mount Tuhua and Pyramid Hill are entirely composed of granitic rocks. Along the Arahura River exposures are common in the first or lowest gorge of the river, and again some miles higher up the stream. Island Hill and Mount Turiwhate show numerous typical outcrops of the formation. Along the Teremakau River high granitic bluffs appear at intervals for some miles, but by far the greatest extension of the Tuhua rocks is on the Hohonu Range, on the northern side of the Teremakau River.

The exposures of the large boss west of Kanieri Lake are chiefly on Mount Graham, and extend southward from that feature towards the Styx River. The width of the eastern band of the Tuhua formation along the Styx River is about a mile and a half; across the summit of Mount Tuhua it is at least three miles and a quarter, while north of the Teremakau River the width has increased to not under six miles and a half. The Mount Graham boss has a maximum width of a mile and a half.

### PETROLOGY OF THE TUHUA FORMATION.

From a textural standpoint the Tuhua rocks are divisible into two distinct phases—the porphyritic facies and the granitoid facies—while mineralogically there are the following types: Aplite, pegmatite, muscovite granite, true granite, granitite, hornblende granitite, and syenite. Of these, aplite and pegmatite are represented only in the dykes, while hornblende granitite and syenite are relatively rare among the plutonics. The prevailing rocks are either granite or granitite, and these may be either porphyritic or granitoid in texture. If of the former facies, the groundmass in which the phenocrysts lie is always granitoid. These various rocks are the products of magmatic differentiation.

The granites have a fairly wide range in chemical and mineralogical composition. Microscopically the true granites are light-pinkish, whitish, or greyish holocrystalline rocks, specked with mica. As a rule, they are of medium grain, though there is a gradation in texture from rocks in which the component minerals are identifiable only beneath a magnifying glass, to others almost pegmatitic. The porphyritic facies is fairly common. The phenocrysts of feldspar, sometimes 1 in. or more in length, are not infrequently in Carlsbad twins, the twinning planes being conspicuous in the hand-specimen. The true granites consist of quartz, feldspar, and both muscovite and biotite. In the muscovite granites biotite is of subordinate importance to muscovite, or is quite wanting. A still more acid phase is one in which there are no ferro-magnesian minerals. When muscovite is lacking but biotite is present in quantity the rock becomes a granitite. The latter when hornblende is the characteristic mineral with quartz and feldspar passes into a hornblende granitite, while in the absence of quartz and a relative increase in the quantity of hornblende and biotite it becomes a syenite.

Beneath the microscope the true granites are seen to be typically automorphic in structure, and to consist when fresh essentially of the following minerals: Orthoclase, microcline, microperthite, plagioclase, biotite, and muscovite, with the accessory minerals—titanite, apatite, pyrite, magnetite, garnet, and possibly zircon. When decomposed, as is not infrequently the case, a number of metamorphic minerals are developed, of which epidote, zoisite, chalcedony, chlorite, and sericite are the most important. The feldspars are the predominating minerals in all the granites. In the true granites orthoclase and plagioclase are about equally distributed. The orthoclase is generally more or less altered to sericite, the alteration of the mineral varying, of course, with the amount of decomposition the rock has undergone. The mineral, as a rule, occurs in simple crystals or in Carlsbad twins. In the porphyritic granites the phenocrysts are shown with their own crystallographic boundaries. The plagioclase is chiefly an acid oligoclase rather than albite, as judged by the angle of extinction on sections showing twinning according to the albite law, and by the appearance of epidote as an occasional alteration product. In the weathered granites the plagioclases show extensive sericitization and minor epidotization, the alteration products arranging themselves along the parallel albite twinning lines. Microcline is also frequently more or less completely changed to sericite, which is developed along the curious cross-hatching characteristic of the parent mineral. The relatively uncommon feldspars, microperthite and microcline microperthite, exhibit decomposition similar to the other minerals of this class. The biotites and original muscovites occur most frequently in rectangular plates or as small irregular areas of no definite outline. The biotites alter most frequently to chlorite, though sometimes to epidote. In the more highly decomposed granites calcite is somewhat common in tiny veinlets in the broken plagioclases and biotites, and also occurs as small areas with definite crystallographic boundaries among the other products of decay. Of the accessory minerals magnetite and pyrite are the most common. Both are found in individuals with idiomorphic outline, and also in small aggregates. Very probably some of the magnetite is titaniferous, as judged by the occasional occurrence of halos of metamorphic titanite surrounding the grains. Titanite is also to be seen in small irregular rhomboids. Apatite, in individuals of hexagonal or prismatic outline, exists as inclusions within the plagioclases and micas, and also independently.

Microscopically the muscovite granites exhibit an absence of biotite, and generally less magnetite and more quartz than the true granites. The granitites in the hand-specimen are somewhat darker in colour than the true granites, while beneath the microscope they show typically an absence of muscovite, except that produced by metasomatic processes. The hornblende granitites and syenites are in general even darker in colour than are the granitites. Microscopically the hornblende granitites show the presence of two ferro-magnesian minerals—biotite and hornblende—in about equal distribution, while in the syenites hornblende is seen to be the prevailing mineral, and in general there is an increase in the quantity of magnetite, and quartz is rare or wanting.

Of these several types of plutonics—true granites, muscovite granites, granitites, hornblende granites, and syenites—true granite tending towards the acidic phase is the prevailing species in the area now being described, and occurs so generally throughout the country covered by the Tuhua rocks that no especial locality need be mentioned. When porphyritic, as is not infrequently the case, it forms very handsome rocks. There are good exposures of porphyritic granite at the base of Island Hill, at the Kawhaka Dam, at the head of Stony Creek, and elsewhere. Muscovite granites and granitites have a fairly general distribution throughout the Tuhua formation. Hornblende granitites and syenites outcrop at the head of Camp Creek on the slope of Mount Turiwhate, on Sawpit Creek at the base of Mount Graham, and elsewhere.

The granites, granitites, muscovite granites, hornblende granitites, and syenites all show very markedly the effect of dynamic influences. The quartzes show undulatory extinction, are sometimes cracked, and even occasionally comminuted. The feldspars, too, all show the decided effect of strain, and in places exhibit the formation of metamorphic halos around the central cores, while the ferro-magnesian minerals are bent and broken.

In places a basic porphyritic granite occurs which both megascopically and microscopically shows the effect of mashing much more strongly than do the ordinary rocks of the Tuhua complex. In the hand-specimen it is seen to be distinctly gneissoid, the large phenocrysts of feldspar and the smaller individuals of both quartz and feldspar being surrounded in faintly wavy lines by ferro-magnesian minerals. Under the microscope the rock shows the usual minerals—quartz, orthoclase, oligoclase, biotite, epidote, sericite, muscovite, pyrite, and apatite—but biotite and epidote are much more important than in the ordinary true granites. The effect of strain is also much more pronounced, the quartzes are not infrequently granulated, the residual feldspars are often surrounded by a halo of secondary minerals (epidote, sericite, and quartz), while the biotites are chloritized and often bent. From general field relations these basic porphyritic granites were considered as definitely part of the Tuhua formation, though they are much more gneissoid than is usual with the latter, and possibly may be really earlier and of the same age as the true gneisses to be later described. The basic porphyritic granites occur typically along the Humphrey's Gully Water-race near the crossing of Stony Creek, on the Arahura River above Stony Creek, on the Hokitika–Christchurch Road near Fitzgerald's, and on the Hohonu Range.

Macroscopically the aplite dykes cutting the Tuhua formation exhibit a fine-textured, beautiful, white rock resembling a crystalline limestone. Microscopically the rock is seen to be more acidic than true granite, as it contains more quartz. It consists essentially of a holocrystalline mozaic of orthoclase, microcline, microperthite, quartz, and muscovite. On the whole there seems less evidence of dynamic movements afforded in these rocks than in the Tuhua plutonics.

The pegmatite dykes show, in general, rocks exceedingly coarse in grain and with occasionally a graphic structure. The following minerals are apparent either in the hand-specimen or beneath the microscope: Quartz, acid oligoclase, microperthite, microcline, orthoclase, muscovite, chlorite, garnet, pyrite, tourmaline, and possibly apatite. The pegmatite and aplite dykes have their most frequent exposures on the Turiwhate Range, and along the Teremakau River. Areas of pegmatite also occur on White's Creek, on the slopes of Mount Graham, and elsewhere.

## PETROLOGY AND DISTRIBUTION OF THE GNEISSES ENCLOSED WITHIN THE TUHUA FORMATION.

It has been mentioned at another point in this chapter that the Tuhua rocks enclose within their boundaries certain gneisses, which are apparently of igneous origin and of quite different genesis from the rocks of the Arahura and Kanieri series, which the Tuhua rocks also include. From the microscopic investigation of the Arahura and Kanieri series it is very evident that the rocks of both series have been derived in the main from the decay of granites, granitic gneisses, or some other acid igneous or metamorphic rock. It is quite possible that the gneisses now being described may represent a remnant of these ancient rocks. Microscopic investigation of the gneisses seems to lend decided evidence in favour of this tentative hypothesis.

Megascopically the gneisses vary considerably in texture, being in places coarse-grained and evenly banded, and again so fine-grained as to resemble a biotite schist. As a rule they are greyish or dark-greyish rocks visibly rich in biotite. The most typical species is an intensely foliated and crumpled mica gneiss, showing narrow but broken layers in which high-coloured minerals predominate, intercalated with others in which ferro-magnesian minerals are the prevailing constituents. This rock is practically in places a mica schist. Beneath the microscope the light-coloured bands are seen to consist chiefly of quartz and feldspar, while in the darker laminæ both these minerals occur in association with biotite and a little muscovite. The feldspars represent acid plagioclase—apparently the principal species—with orthoclase and microcline. The rock is highly strained, all the contained minerals showing marked metamorphism. The quartzes are nearly all granulated, though in places a remnant of a core of a larger original individual still exists, while the older feldspars are all broken and even comminuted. Though the phenomenon of sericitization is rarely seen, new feldspars, especially plagioclase, have abundantly formed, and probably much of the biotite is also secondary. The biotite gneisses are seen to best advantage along the Hokitika–Christchurch Road, a mile west of the crossing of the Rough Wainihinihi Creek. In many places throughout the Tuhua complex small remnants of these early rocks (apparently of igneous origin) occur, and, as has been mentioned, some of the more gneissic phases of the granites may properly be included with them. In general, however, the areas covered by the gneisses are far too small to separate them from the plutonics with which they are so intimately associated.

## METAMORPHIC INFLUENCE OF THE TUHUA INTRUSION.

The actual contact between the Tuhua rocks and the Arahura and Kanieri series is very seldom visible, but there can be no doubt about the irruptive relation of the Tuhua formation, as evidenced by the many inclusions of both the Arahura and Kanieri rocks contained in the former near the contact, by the frequent occurrence of narrow sheets of granite occurring parallel to the stratification of the sedimentaries near the border of the formation, and by the far-reaching metamorphic influence of the Tuhua rocks on both the Arahura and Kanieri series. Still further in the next sheet south of the Hokitika Sheet actual contacts between the Tuhua formation and both series were seen, and the igneous rocks were distinctly irruptive into the latter.

The metamorphic influence exercised by the Tuhua rocks is in places very decided and of great interest. At the contact with the Arahura series the effect is not especially apparent, because there the rocks have been so profoundly changed by dynamic and regional metamorphism that the influence of the intruded rock is shrouded. Very probably, however, the numerous small veins occurring close to the contact on this side represent the deposits from thermal springs, which owed their inception to the heat produced by the Tuhua intrusion.

On Macpherson's Creek there are certain rocks of doubtful origin at the contact with the granite. These rocks are distinctly gneissic in megascopic character, show irregular quartz stringers parallel to the foliation, and have an occasional porphyritic appearance. They are undoubtedly at the base of the Arahura series, and may be simply rocks belonging to this series highly metamorphosed by the intrusive granites and by dynamic agencies, or they may be more correctly correlated with the gneisses described as contained within the Tuhua rocks, which are probably of earlier age than the Arahura series. They contain intercalated with them, however, narrow sheets of undoubted igneous rocks referable to the Tuhua formation. It is hoped that further microscopic investigation will elucidate this and many other difficult points connected with the Tuhua complex.

The Kanieri series at the contact with the eastern belt of the Tuhua rocks show very decidedly the effect of the proximity of the latter, the grauwackes being metamorphosed into beautifully crystalline biotite schists and epidote schists. The extent of the metamorphism gradually diminishes away from the contact, though the whole series is somewhat under its control.

The influence exercised by the Mount Graham boss has not resulted in any great alteration of the intruded rocks, but probably the numerous quartz veins occurring within the Kanieri rocks may be due to the hydrothermal action following the intrusion of the Tuhua rocks.

### Special Areas.

Mount Turiwhate exhibits practically every phase of the Tuhua rocks from the most basic to the most acidic. It shows on its southern slopes syenite rocks, while its top and northern slopes along the Teremakau River present pegmatite dykes, aplite dykes, and quartz veins. All these rocks are the products either direct or indirect of the Tuhua intrusion, and probably exhibit the results of igneous action, aqueo-igneous action, and purely aqueous action. In the section along the Christchurch Road, near Fitzgerald's, intensely corrugated gneisses are apparently intruded by fairly acid faintly gneissoid granites, with which are associated basic porphyritic gneissoid granites, the whole being cut by pegmatite, aplites, and quartz veins, as well as by basic dykes later to be described, and giving a most complex though interesting section.

The Hohonu Range also shows a wide lithological range in rocks of the Tuhua complex. Among the species may be mentioned the prevailing facies, a true granite, epidotized porphyritic granite, muscovite granites, very fine-grained granite, and pegmatite. These various species apparently represent a separation by magmatic differentiation.

### Economic Uses for the Tuhua Rocks.

All the Tuhua rocks are more or less jointed, sometimes very irregularly, again with decided uniformity. The joint planes of the granites of the lowest gorge of the Arahura dip at 45° to the westward and trend in a direction north 40° west, splitting the granite into regular blocks 1 ft. to 2 ft. thick. On Flat Creek, a tributary of the Arahura from the south, the faintly gneissoid granite is much jointed in three directions, giving cuboidal blocks. The strike of the master joints is south 45° west, while the dip is to the south-east at less than 40°. The dip of the jointing planes of the light-grey granite on the Humphrey's Gully Water-race, just south of the crossing of Johnston's Creek, is 68° towards the south-west, while the strike is about north 24° west. These planes break the granite into irregular slabs 1 ft. or less in width.

Undoubtedly very much of the granitic rock of the Hokitika area is suitable for building and ornamental purposes. For more ordinary uses, such as heavy masonry, wharves, piers, houses, and public buildings, the true granites and granitites, which are scarcely perceptibly gneissoid, are certainly the most suitable. In some places these rocks are excessively decomposed on the surface, but in many other localities are sufficiently fresh to be used commercially with advantage. Again, at certain points the joint planes, which have an important bearing on the facility of working granite, occur too irregularly or at too frequent intervals to render the rock easily quarryable. However, there are a number of places where on the whole it is fresh, evenly grained, and favourably jointed, and where it is in a suitable position to be easily transported to the coast for shipment. Among granites occurring in such favourable localities may be mentioned the light-greyish, medium-grained granite from the lowest gorge of the Arahura, and the pinkish and greyish granites outcropping in many places along the eastern slopes of Mount Tuhua, just south of the Arahura. Many of the less gneissoid phases of the latter are especially handsome, and bear a resemblance to the famed granites of Aberdeen in Scotland.

It is unfortunate that the Tuhua rocks exposed along the Christchurch Road are unsuitable for building purposes. They are not sufficiently uniform in texture, and are too gneissoid to be commercially valuable. But an area quite as accessible as this point is to be seen at the bluffs on the Styx River, where pinkish and greyish granites of good building quality outcrop within fifteen miles of Hokitika. The railway from Greymouth to Otira passes close to the base of the Hohonu Ranges, in which there is much granite of fine quality. Doubtless with the continuation of the railroad to Christchurch much of this will be utilised for commercial purposes.

The most suitable of the Tuhua rocks for ornamental uses, such as for façades of buildings and for tombstones, are the porphyritic granites with a pinkish or light-greyish groundmass, and with phenocrysts of pink, white, or greyish feldspar. The most beautiful of these rocks are to be seen on the north slope of Island Hill, especially near the Kawhaka Dam, where they are within easy access of a good road to the coast.

# CHAPTER VIII.

## THE POUNAMU FORMATION.

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### Content of the Pounamu Formation.

The Pounamu formation contains the most basic of the igneous rocks of Westland, and represents a series chemically opposite to the pegmatites and aplites, which are a phase of the Tuhua intrusion. The rocks of the Pounamu formation which have generally been profoundly influenced by static metamorphism, and those of the Arahura series which have been very extensively altered by the intrusion of the Pounamu irruptives, are of marvellous variety, and present phenomena of great petrographical interest. So numerous are the species of minerals found in the Pounamu formation that it is not infrequently referred to as the "mineral belt."

The original parent cruptive rock from which the great variety of secondary rocks have been derived was evidently either dunite, olivinite, or a similar olivine rock composed chiefly of magnesian silicate. Megascopically the secondary rocks are generally massive, though sometimes faintly schistose. The following varieties are well recognised: Much altered olivinite or dunite, serpentine rock of various colours, serpentine-talc rock, serpentine-talc-carbonate rock, talc rock, talc-serpentine-nephrite rock, serpentine-tremolite rock, muscovite-serpentine rock, and actinolite rock. In addition there are many other combinations, mainly or partly of hydrated magnesian silicates, of minor importance and of rarer occurrence than those just enumerated.

The metamorphic schists, which have resulted from the Arahura rocks by the intrusion of the Pounamu irruptives, are of a variety as great as are the secondary rocks of the Pounamu formation itself, which they sometimes closely resemble. The most important are talc schist, serpentine schist, epidote-amphibole schist, tremolite-carbonate schist, magnetite-serpentine schist, pyrite-serpentine-carbonate schist, and muscovite schist.

An immense number of minerals have been found within the Pounamu rocks and within the metamorphic schists, which owe their extraordinary character to the intrusion of these rocks. The following is only a partial list of the species occurring within this interesting belt, but it includes those of most striking characteristics as well as those most frequently encountered: Pyrite, chalcopyrite, malachite, chrysocolla, magnetite, chromite, hæmatite, limonite, calcite, dolomite, siderite, various magnesic ferrous carbonates such as ankerite, &c., quartz, nephrite (of various varieties), serpentine, actinolite, tremolite, asbestos (with the variety known as mountain leather and numerous allied varieties), epidote, muscovite, bowenite, chrysotile, chlorite, chrome mica, and ruby, the whole forming a wonderful natural mineralogical museum.

### Mode of Occurrence of the Pounamu Rocks.

The Pounamu rocks are generally intruded in the form of sills or sheets parallel to the stratification of the Arahura series. In some places, however, they cut these rocks at very acute angles, and often include portions of the Arahura rocks within them. The Pounamu formation exists not as a single belt, but as several parallel or almost parallel bands. None of these bands are exposed continuously across the sheet, though the outcrops may be prominent for a mile or more. Again, where the actual Pounamu rocks do not appear on the surface, metamorphic schists, influenced by the impregnation of magnesian solutions, sometimes appear along the strike of the Pounamu belt. These solutions probably arose from a magnesian magma which was not at these points intruded to the present denudation level in the sedimentary rocks. In some places two or more parallel bands of Pounamu rocks occur close together, separated by wider belts of the intruded rock. In places a band may branch giving two or more sub-bands, which may continue an independent existence without rejoining. It is possible that these various bands may represent the opposite limbs of folds, though this does not seem probable, because the Pounamu rocks proper are only slightly schistose—not nearly so much so as would be expected had they been involved in the movements which affected the Arahura rocks. It is most likely that the Pounamu rocks were intruded along the lines of weakness at the base of the monoclinal folds formed in the Arahura series.

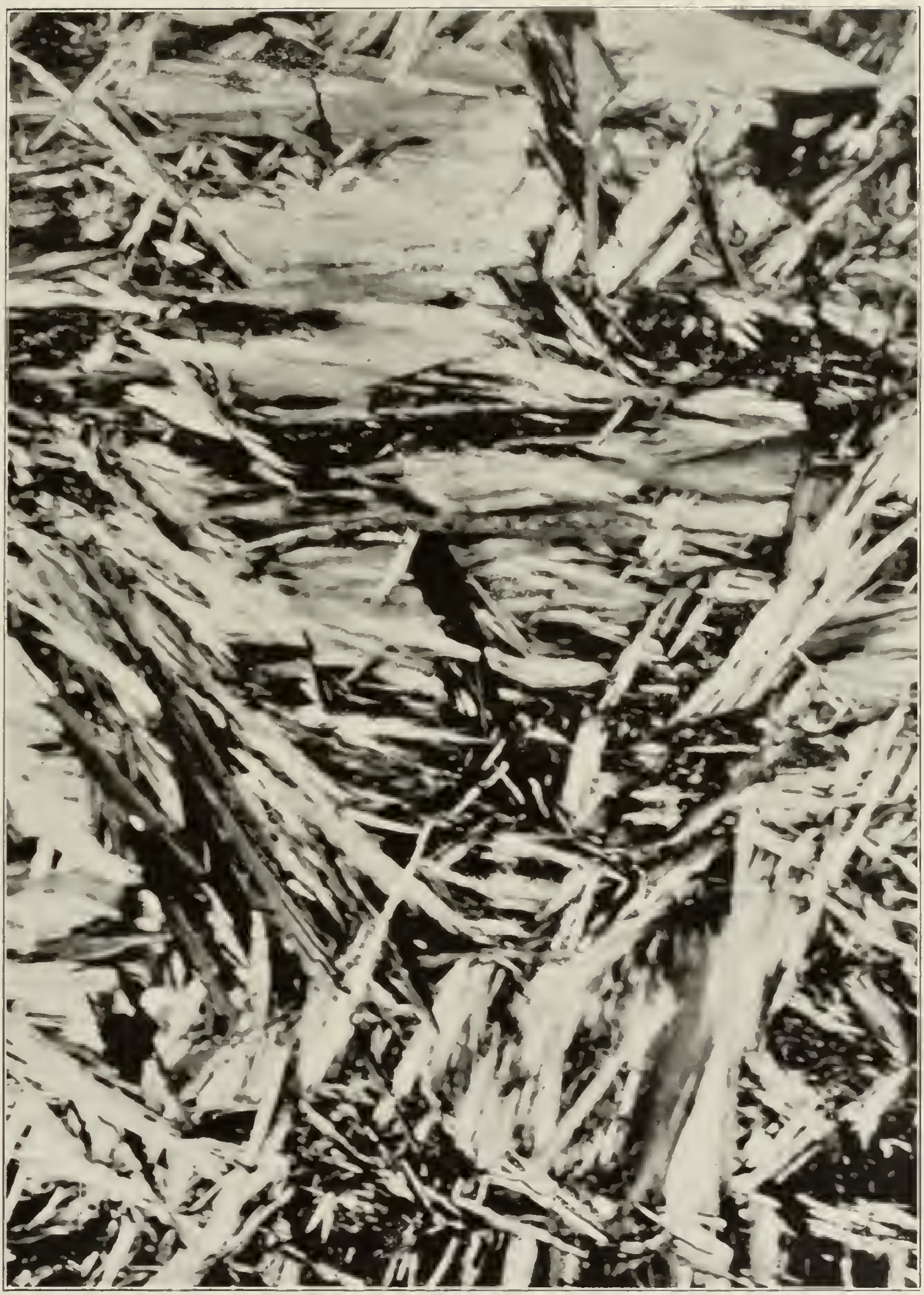
The Pounamu rocks occupy some of the most inaccessible country within the area covered by the Hokitika Sheet. The McArthur Crags, where there are extensive outcrops of the formation, are of especially rough and broken topography. Some exceptional precipices were practically unscaleable, and here the formation had to be judged by the detritus which fell from above on the talus at the foot of the cliffs. Moreover, most of the outcrops of the formation are at high altitude, the most prominent being above 4,000 ft., in country which was actually free from snow for a very short time during the past unfavourable season. The rugged nature of the country, and more especially the very bad weather which prevailed practically the whole time when it was possible to make examinations on the top of the ranges, prevented this most interesting portion of the country being investigated as adequately as it deserved, and prohibited a more careful delineation of the various belts.

The age of the Pounamu rocks cannot be ascertained with any degree of accuracy. They are certainly later than the lower part of the Arahura series which they intrude. Owing to the fact that olivine is the principal mineral in the basic volcanics of Koiterangi Hill, it is possible that the Pounamu formation, on account of this lithological similarity, may be of the same age as the basic dykes, though this suggestion may be considered as purely hypothetical. It is, however, equally possible that the formation, which is in places slightly schistose, may be of much greater antiquity than these basic dykes.

### General Distribution of the Pounamu Formation.

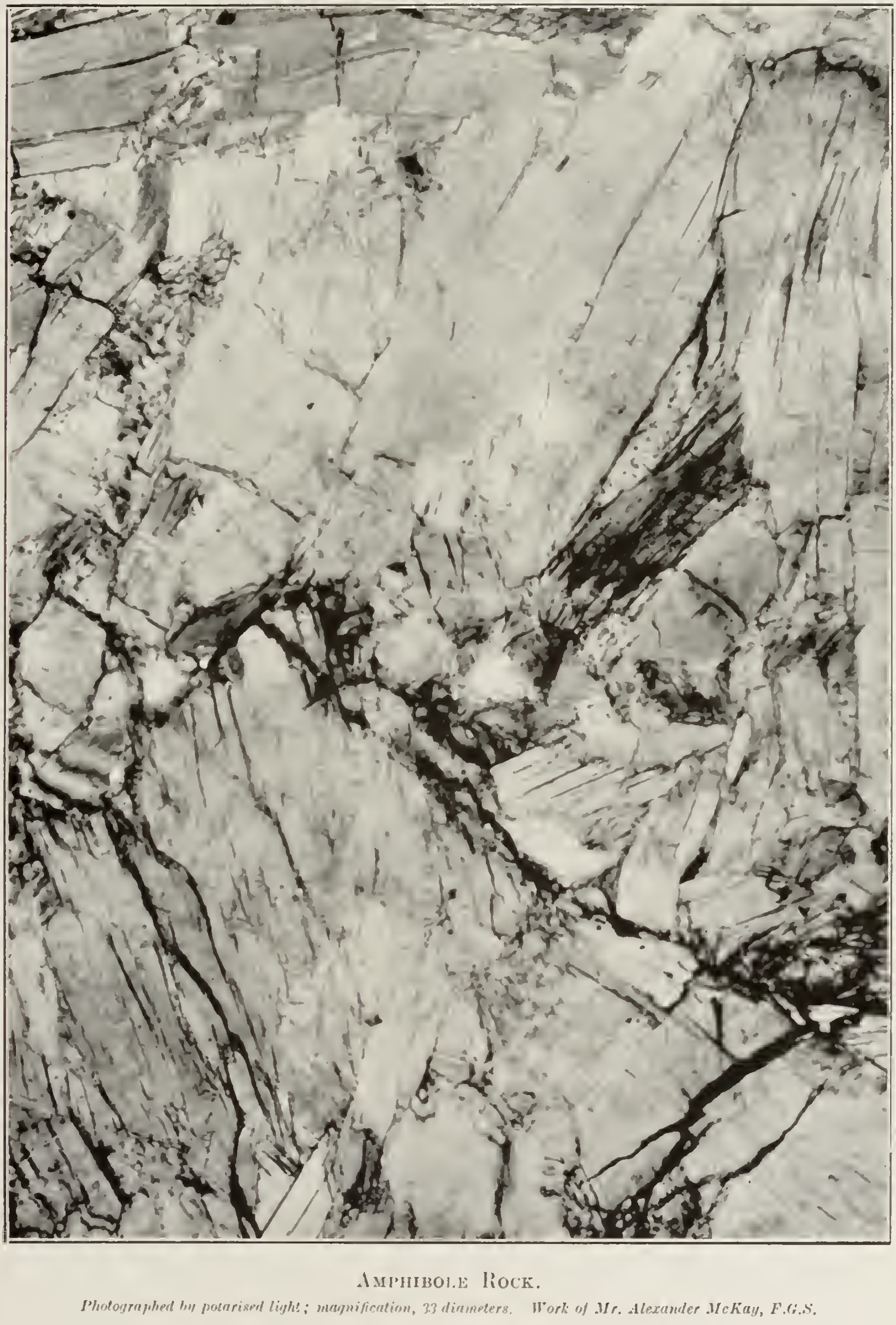
The Pounamu formation does not appear *in situ* on the Styx River. However, numerous boulders of the magnesian rocks are found in the stream-bed, and the formation probably traverses the river at or near the most easterly of these erratics, or some four miles and a half west of Styx Saddle. Pounamu rocks outcrop prominently on Mount Brown Range, between the headwaters of Clarke's and Price's Creeks, and form the *massif* of the lofty precipitous bluff of McArthur Crags, facing Olderog's Creek on its western side. Several bands of the formation traverse the headwaters of the Rough Wainihinihi Creek and Griffin Creek, and appear on the range southward from the Rough Wainihinihi towards McArthur Crags. The formation crosses Griffin Creek above the lower gorge and outcrops extensively on the high hills on the south-western side. It traverses the Taipo River between the top of the lower gorge and the mouth of Rocky Creek. There are somewhat doubtful exposures of the formation at the head of Larry's Creek, and it is said to appear extensively on the northern flanks of the Bald Range.

Pounamu rocks, consisting chiefly of foliated serpentine, are seen in Macpherson's Creek, though it is not absolutely certain that they are in place. If they are not erratic they probably



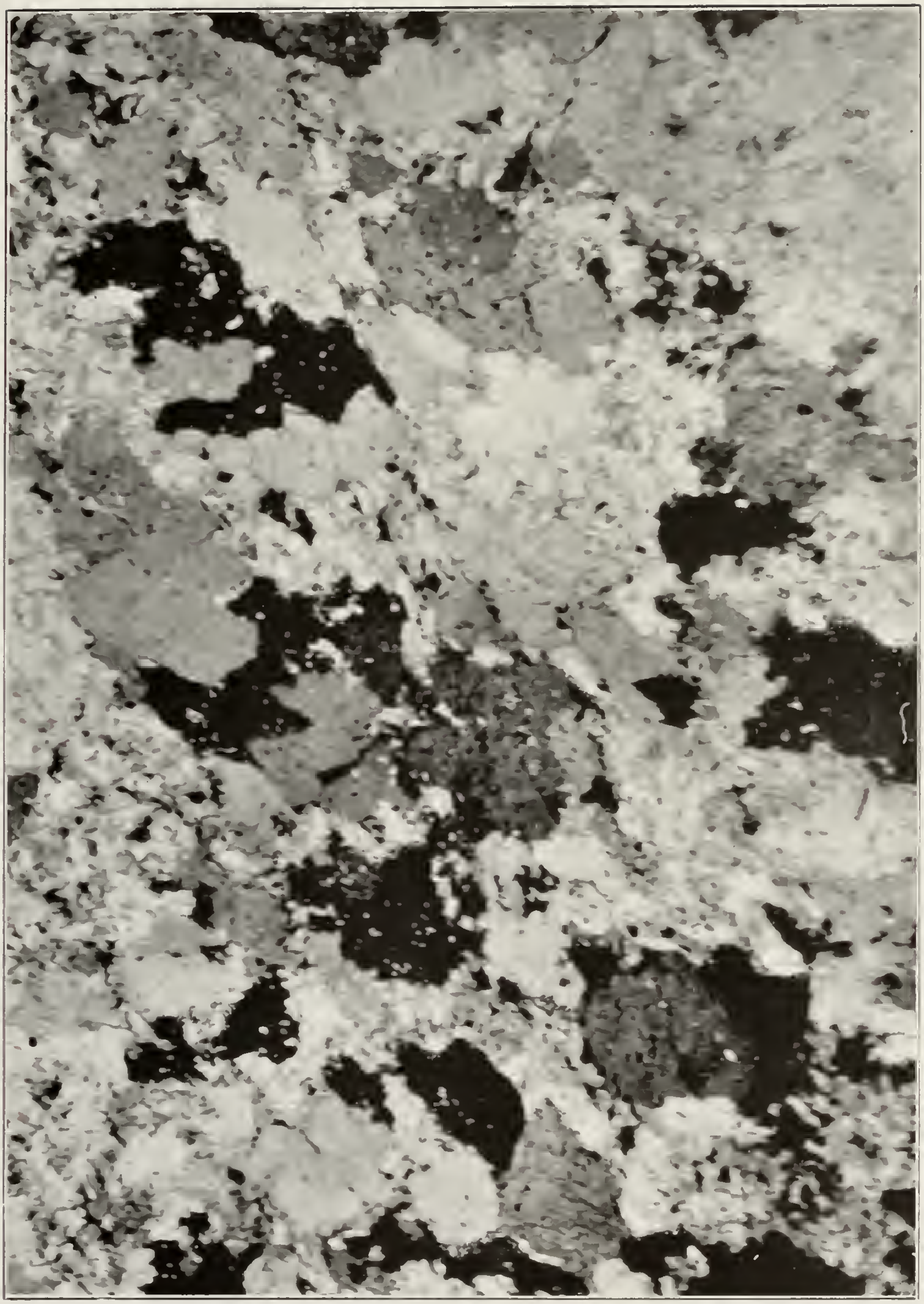
Altered Olivine Rock.

*Photographed by polarised light; magnification, 34 diameters. Work of Mr. Alexander McKay, F.G.S.*



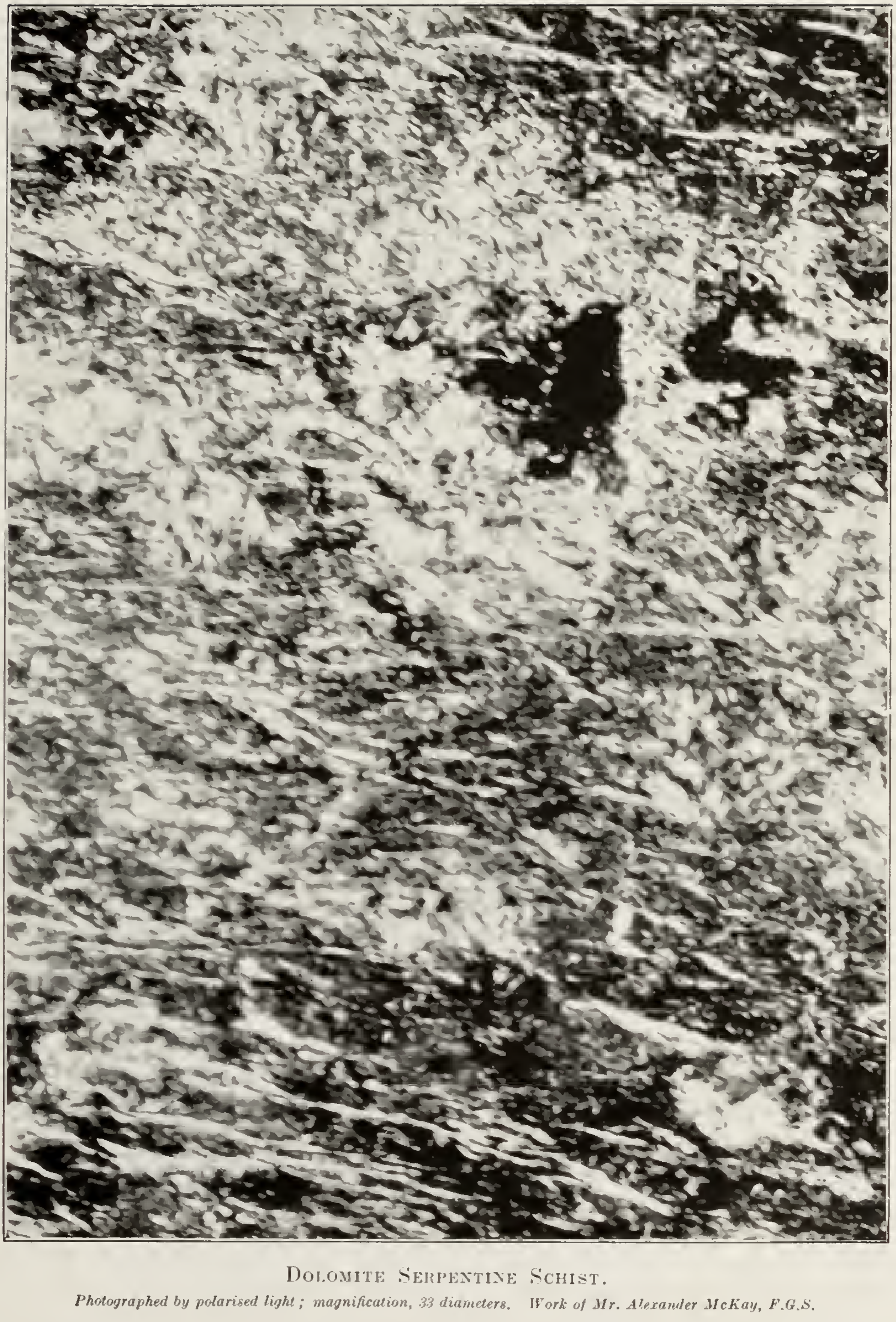
Amphibole Rock.

*Photographed by polarised light; magnification, 33 diameters. Work of Mr. Alexander McKay, F.G.S.*



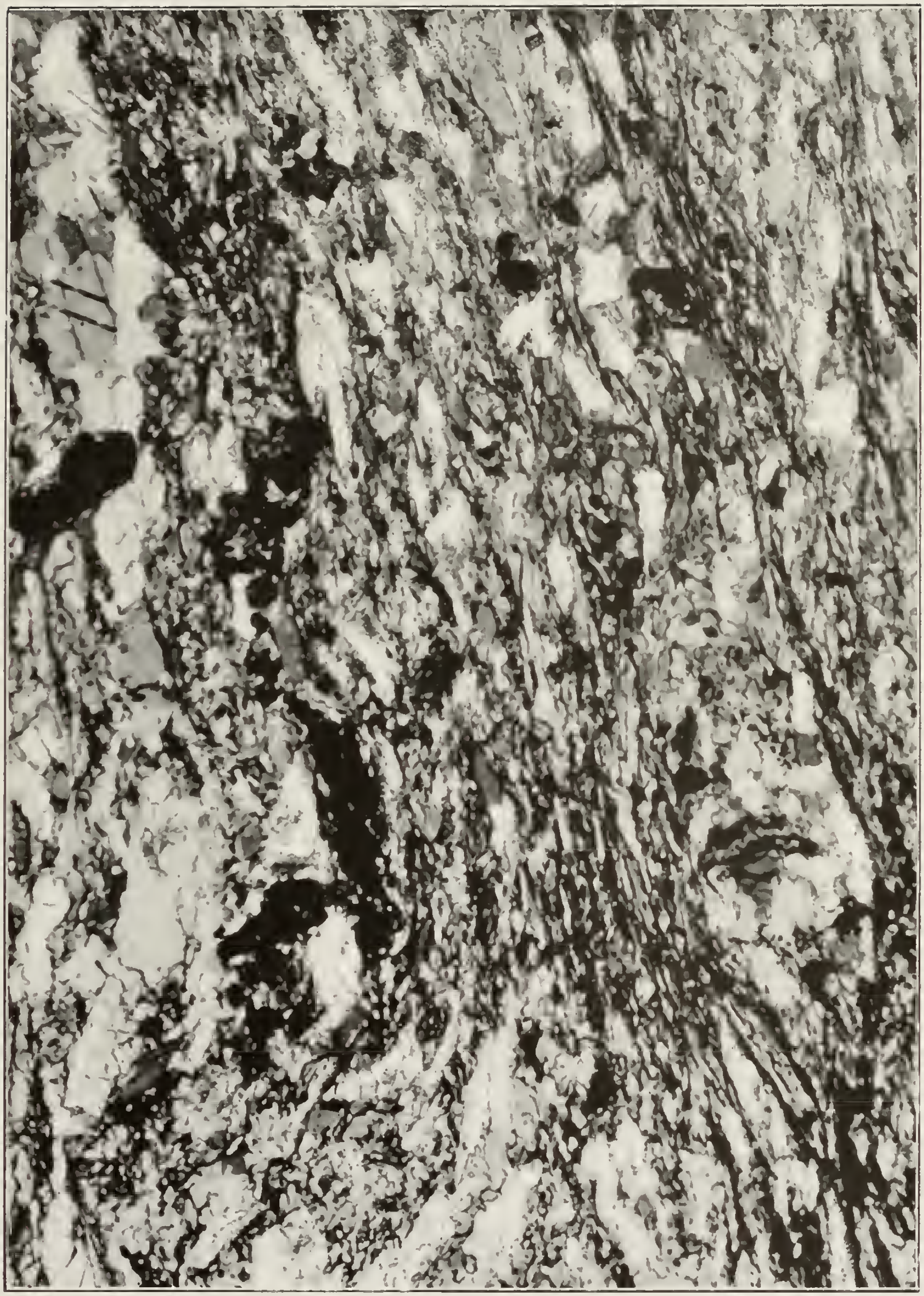
Dolomite Talc Schist.

*Photographed by polarised light; magnification, 33 diameters. Work of Mr. Alexander McKay, F.G.S.*



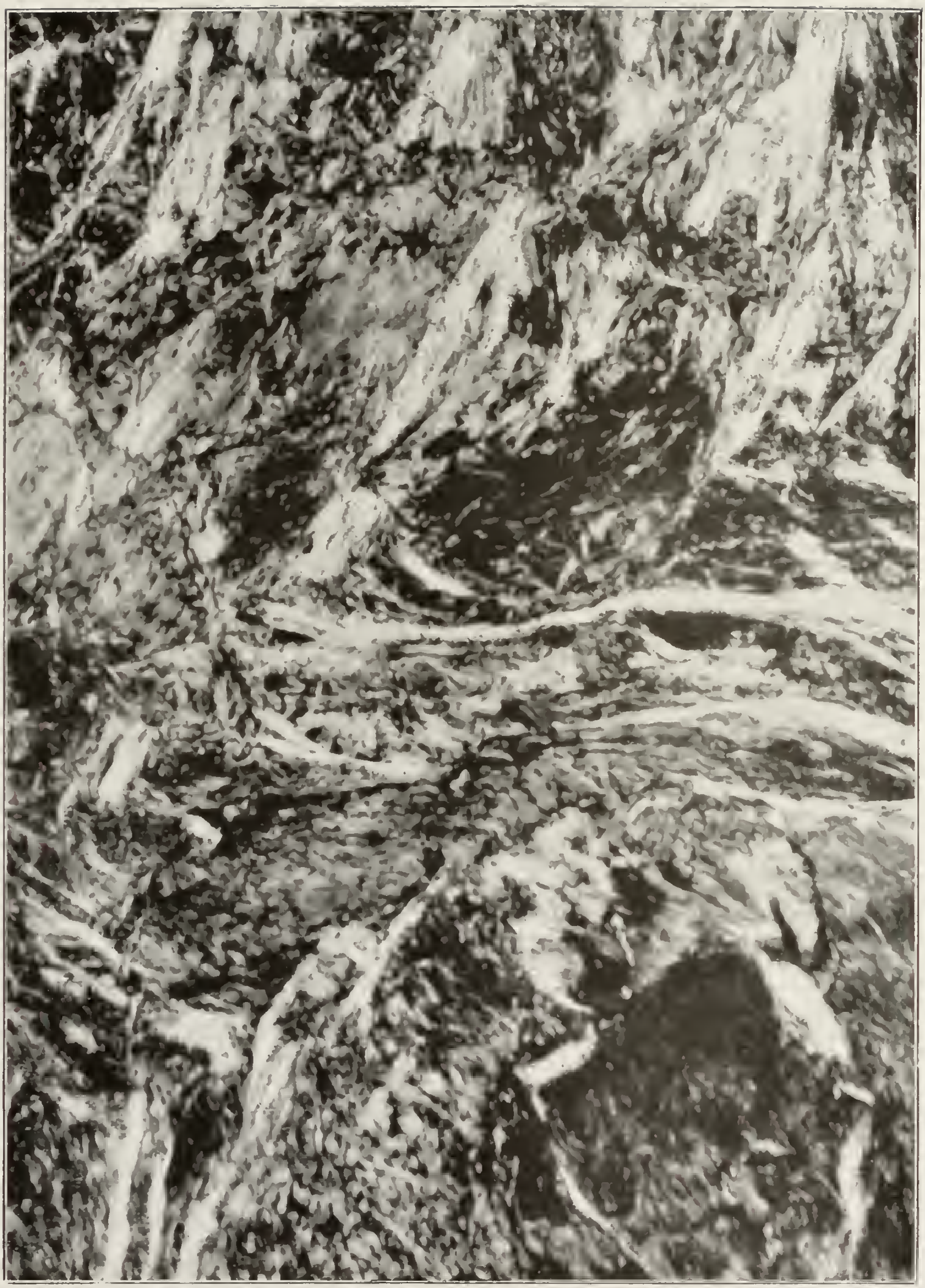
DOLOMITE SERPENTINE SCHIST.

*Photographed by polarised light; magnification, 33 diameters. Work of Mr. Alexander McKay, F.G.S.*



TREMOLITE CALC-SCHIST.

*Photographed by polarised light; magnification, 33 diameters. Work of Mr. Alexander McKay, F.G.S.*



SERPENTINE SCHIST.

*Photographed by polarised light; magnification 33 diameters   Work of Mr. Alexander McKay, F.G.S.*

represent the same belt of Pounamu formation as is said to have been traversed in the long tunnel carrying the water from the small dam at the head of the Waimea Water-race to the race-canal to the westward.

### PETROLOGY OF THE POUNAMU ROCKS.

It has already been mentioned that the Pounamu rocks consist chiefly of several varieties of much altered olivinite, serpentine rock, serpentine-talc rock, serpentine-talc-carbonate rock, talc rock, talc-serpentine-nephrite rock, actinolite rock, and muscovite-serpentine rock. All these are phases of the metamorphism of the original dunite or olivinite rock by deep-seated waters which either accompanied or followed the intrusion of the Pounamu rocks, or of surface waters which have been active ever since the intrusion. Fresh dunite, so far as is known, does not appear in the area covered by the Hokitika Sheet, but it outcrops in the Hokitika Gorge within the Mikonui Sheet, in the same geological horizon as the area now being considered. Megascopically it is a dark-greenish massive rock, while microscopically it is seen to consist chiefly of a mosaic of fresh olivine with finely disseminated chromite and a little pyroxene. In the absence of chromite the rock may be spoken of as olivinite. Fresh dunite is rare, and is almost always more or less serpentinised. In the Hokitika area the altered dunites or olivinites very frequently exhibit the microscopic characters of the undecomposed irruptives, but beneath the microscope the almost complete alteration to serpentine, with only an occasional residual core of olivine, is visible.

In the serpentine rock practically no olivine remains. They are massive rocks of rich dark-green, grey-green, and light-yellowish-green colour, and very frequently they weather a deep brown, which gives them an easily recognisable outcrop. Almost always they contain more or less carbonate and talc, and with the increase of these two constituents they grade into serpentine-carbonate rocks and serpentine-talc rocks. Under the microscope the rocks consist chiefly of radiating prisms of serpentine of a light-greenish colour, with which is associated small patches of carbonate, talc, disseminated magnetite, limonite, and sometimes chromite. Massive serpentine rock is of wide occurrence in the Pounamu formation within the Hokitika area, being prominent on the McArthur Crags, on the Rough Wainihinihi, on Griffin Creek, and it is said along the northern slopes of Bald Range.*

The serpentine-talc rock differs from the true serpentine rock in the presence of a great deal of talc associated with the serpentine and other minerals found in the serpentine rock proper. Macroscopically it is a soft light-greyish-green rock, streaked with light-green or white, and generally very soft. It nearly always contains a little amphibole, and some carbonate, which is generally dolomite, but may be calcite, siderite, or some of the ferro-magnesic carbonates. Thus it is sometimes weathered a brownish colour by the oxidation of iron-carbonate. With the predominence of carbonate over talc the rock passes into the serpentine-carbonate rock. Both serpentine-talc rock and serpentine-carbonate rock have a wide distribution at the Taipo Gorge, along the Rough Wainihinihi and Griffin Creek, and elsewhere. In some places the rock consists almost entirely of talc of greater or lesser purity, and it may then be spoken of as a talc rock. The talc rock is generally massive and almost structureless. Most frequently it is of a dirty grey or white colour, but occasionally it is of a beautiful pale-green shade. Sometimes it is fairly translucent in thin chunks. In large masses it is very seldom foliated, though it sometimes occurs in this form in small recrystallized patches of great purity, with calcite and dolomite in the main mass of the ordinary talc rock.

The mineral nephrite wherever observed occurs as rounded segregations in talc rock or talc-serpentine rocks. The segregations vary in size from 1 in. or less in diameter to 2 ft., or even more, in lateral dimension As a rule, they average less than 1 ft. in width. With the wearing-away by abrasion or by decomposition of the enclosing talcose or serpentinous matrix, the segregations are freed as rounded masses generally covered by a coating of serpentinous material derived from their own decay. It is these segregations which were transported by the Arahura and other glaciers in the period of maximum ice-advance, and which appear in the glacial *débris* along the lower Arahura and other streams as the famous "greenstone" boulders of the West Coast.

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* Mines Reports, 1893, C.-3, p. 172.

According to Dana pure nephrite is a mineral of somewhat variable composition, though it is supposed to be massive amphibole closely allied to actinolite. In his recent text-book (1904) Dana gives a number of analyses of New Zealand nephrite which are inserted below for reference:—

| $SiO_2$. | $Al_2O_3$. | FeO. | MnO. | MgO. | CaO. | Ign. | $K_2O$ and other Alkalis. | Total. |
|---|---|---|---|---|---|---|---|---|
| 57·75 | 0·90 | 4·79 | 0·68 | 19·86 | 14·89 | 0·68 | .. | 99·93 |
| 51·70 | 0·95 | 7·62 | Trace | 23·50 | 13·09 | 2·42 | .. | 99·28 |
| 56·55 | 0·21 | 6·21 | .. | 19·78 | 13·60 | 2·81 | .. | 99·16 |
| 57·35 | 0·22 | 5·94 | .. | 20·70 | 13·47 | 3·13 | .. | 100·81 |
| 57·38 | 0·22 | 3·50 | .. | 22·32 | 13·68 | 2·78 | 0·69 | 100·57 |
| 56·34 | 1·60 | 4·86 | .. | 20·23 | 13·51 | 3·57 | 0·58 | 100·69 |
| 56·73 | 3·22 | 5·96 | Trace | 19·42 | 13·24 | 0·83 | .. | 99·40 |

There are several distinct varieties of nephrite which are known to the Maoris as "pounamu," "tangiwai," "kawakawa," &c. Pounamu is the most common variety, and from it the formation of magnesian eruptives in which it occurs receives its distinctive name. It is a deep-green, semi-transparent mineral, often blotched with dark opaque patches. Its hardness varies somewhat, though it is generally harder than quartz. Tangiwai is of a greenish-grey or dull-green colour, is harder than Pounamu and most frequently occurs fissiliform. Not infrequently bowenite is associated with it, which makes it much softer. Talc-nephrite rocks and nephrite-serpentine rocks occur most frequently at the head of Griffin Creek.

Muscovite-serpentine rocks are not of common occurrence in the area at present being described, though large boulders were found in Olderog's Creek, which had evidently descended from rock *in situ* on McArthur Crags. A rock consisting chiefly of muscovite, and probably allied to the muscovite-serpentine rock, is mentioned by Mr. A. McKay as occurring in the Bald Range, between Rocky Point in the Teremakau Valley and the gorge of the Taipo River. The muscovite-serpentine rocks consist essentially of muscovite and serpentine, but there is always a great deal of carbonate, generally dolomite, with occasionally rubies and other accessory minerals.

Actinolite rocks are found chiefly in the form of boulders in Griffin Creek, Cold Creek, and elsewhere, but are also to be observed *in situ* as narrow veinlets in connection with the talcose rocks in the same localities. They are handsome rocks varying in colour from very pale nile-green to deep emerald-green. Not infrequently the actinolite occurs in large radiating sheaves, 1 in. or more in length, which are terminated by other sheaves starting from another centre.

It has been mentioned that the schists which have been metamorphosed, especially by the Pounamu intrusions, include the following varieties: Talc schists, serpentine schists, epidote-amphibole schists, tremolite-carbonate schists, magnetite-serpentine schists, pyrite-serpentine-carbonate schists, and muscovite schists. These schists are so intimately connected with the Pounamu intrusion that a discussion of the Pounamu formation would be incomplete without a description of these products of their metamorphism. It is to be distinctly understood, however, that these schists belong to the Arahura series, but owe the immense number of magnesian minerals which they contain, as well as magnetite, pyrite and other metamorphic minerals, to the widespread impregnation by the magnesian solutions accompanying the Pounamu intrusion.

The talc schists appear in connection with almost every outcrop of Pounamu rocks. They are of beautifully variegated colours—vivid nile-green, dark-brown, pale whitish-green, and dull-grey. They are always soft, friable rocks, distinctly and often crenately foliated. Evidently they have been derived from chlorite and other ferro-magnesian schists by the influence of magnesian solutions. In places there seems to be a gradual transition along the line of strike between the talc schists, and chlorite and other ferro-magnesian schists. Under the microscope the talc schists are seen to consist essentially of talc, with lesser amounts of serpentine, actinolite, &c.

The following two analyses are inserted for comparison and to exhibit the influence of magnesia-bearing waters. No. 1 is from near the edge of the Pounamu intrusives in Clarke's Creek, unchanged by the intrusion, while No. 2 is from the Rough Wainihinihi, and profoundly influenced by the Pounamu intrusion in the immediate vicinity:—

*No. 1.*

| | Per Cent. |
|---|---|
| Silica | 63·85 |
| Alumina | 17·40 |
| Ferric oxide ($Fe_2O_3$) | 1·08 |
| Ferrous oxide ($FeO$) | 4·64 |
| Manganous oxide | 0·10 |
| Chromic oxide | Nil. |
| Titanium-oxide | 0·61 |
| Lime | 2·01 |
| Magnesia | 1·75 |
| Soda ($Na_2O$) | 3·04 |
| Potash ($K_2O$) | 3·26 |
| Sulphuric anhydride ($SO_3$) | Nil. |
| * Loss above 100° C. | 1·62 |
| Loss at 100° C. | 0·40 |
| | 99·76 |

* Includes carbonic anhydride ($CO_2$), 0·68.

*No. 2.*

| | Per Cent. |
|---|---|
| Silica | 50·45 |
| Alumina | 8·16 |
| Ferric oxide ($Fe_2O_3$) | 4·20 |
| Ferrous oxide ($FeO$) | 2·91 |
| Manganous oxide | 0·08 |
| Chromic oxide | 0·20 |
| Titanium-oxide | 0·15 |
| Lime | Nil. |
| Magnesia | 27·65 |
| Soda ($Na_2O$)<br>Potash ($K_2O$) | 0·18 |
| Sulphuric anhydride ($SO_3$) | Nil. |
| * Loss above 100° C. | 5·72 |
| Loss at 100° C. | 0·25 |
| | 99·95 |

* Includes carbonic anhydride ($CO_2$), nil.

Serpentine schists are, like the talc schists, of very wide distribution. They resemble the serpentine rocks of the Pounamu formation very closely, both megascopically and microscopically. Generally, however, they are of much finer grain and exhibit a remarkably schistose structure. Talc is always present, and magnetite is generally widely disseminated.

The epidote-amphibole schists have not been observed *in situ* in the area under consideration, though as boulders they are frequently to be seen in Griffin Creek and elsewhere. Macroscopically the rock is a beautiful straw-green colour, streaked with very narrow seams of dark-green and wider bands of whitish material. The rock weathers a deep purplish-brown. Under the microscope epidote is seen to be the principal constituent, with amphibole, quartz, chlorite, and a little calcite.

Tremolite-carbonate schists, which in places grade into a magnesian limestone, are not uncommon in connection with the magnesian belt, and are especially common near the head of Clarke's Creek. The hand-specimen shows a mottled greyish and whitish crystalline rock, in which under the microscope the following constituents are easily identifiable: Calcite, with probably some dolomite, tremolite, and some magnetite. In some places the magnetite in irregular areas is almost the prevailing mineral present.

The magnetite-serpentine schists are finely laminated rocks of dark-greenish colour, containing a great many crystals of magnetite. The crystals nearly all show perfect octahedral forms, which are sometimes distorted and not infrequently twinned. As a rule, the axes of the crystals are under ¼ in. in length, but may be as long as ½ in. On weathering the crystals of magnetite remain on the surface, and in places are to be picked up in handfuls.

The pyrite-serpentine-carbonate schists are rocks of great beauty, and show numerous magnificent fresh sparkling crystals of pyrite in a foliated rock, composed chiefly of layers of dark-green talc and serpentine with minor laminæ of carbonate and light-green serpentine. The pyrite crystals are evidently always in the form of cubes and exhibit beautiful striations. The crystals are of variable size, from those scarcely visible with the unaided eye to others ½ in. or more in diameter. The pyrite-serpentine-carbonate schists and the magnetite-serpentine schists occur chiefly as inclusions in the Pounamu rocks in Nephrite Creek and in Magnetite Creek, in the Rough Wainihinihi–Griffin Creek area. The presence of so much pyrite indicates considerable solfataric action following or during the period of Pounamu intrusion.

The muscovite schists are greyish-green rocks, specked with silvery or greenish flakes of muscovite. They exhibit practically the same essential minerals as the muscovite-serpentine rocks belonging to the Pounamu formation proper, but are distinctly more schistose in structure.

## SPECIAL AREAS OF THE POUNAMU FORMATION

### *(a.) Clarke's Creek Area.*

The rocks of the Pounamu formation form the broken and precipitous country which marks the crests of the Mount Brown Range, between the source of Clarke's Creek and Price's Creek. The barometer showed the elevation of the summit here to be 4,390 ft., and at the time of examination snow concealed everything excepting the steepest inaccessible faces. The trend of the Pounamu belt would appear to be approximately north-east, and its inclination south-westward at high angles, while its dimensions transverse to the trend are not inconsiderable.

Dark-green massive serpentine rock (with chromite) constitutes the great mass of the formation, and in this, slickensided joints and faces are everywhere apparent. Many of these joints include narrow ribs of fibrous amphibole, impure asbestos, mountain wood, &c. With this serpentine rock is associated a talc-carbonate-serpentine rock in which segregations of these several constituent minerals are conspicuous. The serpentine of this variety is frequently fibrous, and the talc includes small blebs of nephrite. Tremolite-calcite schists often mark a transition from the Pounamu intrusives to the ordinary dark-grey mica schists, though both schists belong to the Arahura series.

### *(b.) McArthur Crags Area.*

On the steep southern slopes of McArthur Crags overlooking the Arahura River valley, the first outcrops of the Pounamu formation appear, at an elevation of 3,110 ft., and from here upwards the broken and craggy nature of the crests is in part due to the existence of this intrusive belt. Massive serpentine rock with chromite, intersected by joints carrying ribs of slickensided and fibrous amphibole, especially asbestos, forms the great portion of the formation, and the rocks here are identical with those of Clarke's Creek area. The fairly well-defined hanging-wall of a large mass, dipping about 50° to the eastward and rising above the general surface of the country, is a conspicuous feature, the more so on account of the characteristic dun colour that the weathered surfaces assume. The width of the formation is not apparent, and it is probable that several bands exist, separated by sheets of greater or lesser extent of the intruded schistose rocks.

As judged from consideration of the boulders occurring in Olderog's Creek, which are shed from the eastern flanks of the northern continuation of these crags, talc rock, with segregation nodules of nephrite, probably occurs in the belt. Some large nephrite boulders of particularly good quality have been obtained in the bed of Olderog's Creek and in the Arahura, just below its junction with this stream. Likewise boulders of a muscovite-serpentine rock, which is the matrix of numerous minute rubies, have been found in such localities as to indicate that this belt is their place of origin.

### *(c.) Rough Wainihinihi Area.*

From the bed of the wide open valley of the upper portion of the Rough Wainihinihi Creek (elevation 3,294 ft.) three or more separate bands of Pounamu rock are visible above the mountain-scrub line on the south side of the valley. These are conspicuous owing to the greater resistance this rock offers to weathering agents, and to the characteristic brown colour of the exposed surfaces. The bed of Cold Creek, one of the tributaries of the Rough Wainihinihi Creek, has for some distance been eroded along the outcrop of one of these bands, which is probably identical with the occurrence in Nephrite Creek to the north of Razorback Ridge, which will be later described. At a point 600 ft. above the bed of the main creek and distant 25 chains therefrom, Cold Creek bifurcates, and here two separate bands of Pounamu rocks exist which may have their point of junction in the vicinity. A local deformation of the strata which probably accompanied the intrusions is apparent at this point. The main band is 21 ft. in width, and consists principally of talc carbonate rock, with inclusions of a greenish talcose schist.

Some 4 chains down Cold Creek from the forks a good section is exposed in the actual creek-bed. Considered transversely to the strike from west to east this shows:—

(*a*.) 6 ft. of massive talc-carbonate rock, with nodules and streaks of inferior "greenstone" and thin wavy bands of a highly ferriferous serpentinous rock.

(*b*.) 6 ft. of greenish-grey talc-carbonate rock, foliated and slickensided with a few inclusions of altered schists.

(*c*.) 2 ft. 6 in. of more massive talcose rock, with wavy bands of dark-green actinolite rock.

(*d*.) 19 ft. of altered Arahura rocks, consisting of highly coloured talcose schists, very soft and greasy, and showing almost every shade of green, grey, and brown.

Traversing these schists in a direction parallel to the foliation, and at a distance of 3 ft. 6 in. from the eastern border of the massive talcose rock (*c*), is a small but well-defined fissure ranging from 2 in. to 4 in. in width. The wall rocks of this fissure show crustification and numerous radiating needle-like prisms of actinolite. A gradual transition in the stages of alteration of the schists on each side of this fissure is apparent, so that possibly it represents the channel through which the magnesian water which altered the schists on either side circulated.

To the east of Magnetite Creek, another tributary of the Rough Wainihinihi, on the south side of the valley and at an elevation of 725 ft. above the bed of the main creek, a Pounamu intrusion about 1½ chains in width was located, trending north 30° east, and inclining east at an angle of 54°. What is apparently the northern continuation is visible high up on the opposite side of the main valley. The main mass of the rock here is the massive serpentine rock, with chromite, while fibrous serpentine and asbestiform amphiboles are common in planes of fracture and jointing. The dun-coloured weathered surfaces have often a scoriaceous appearance, and small green-glassy blebs of fibrous serpentine are conspicuous. Talc and carbonates occur in streaks and nodules, together with inferior nephrite. Inclusions of the intruded schists appear in places, and these are altered by the action of the magnesian solutions, being coloured light green to dark green, while in them tremolite and actinolite have been developed. A soft dark-green serpentine schist in which large magnetite crystals are bespeckled throughout was found in some of the talus *débris* derived from this belt.

At the actual junction of Magnetite Creek with the Rough Wainihinihi large blocks of the Pounamu formation are seen on the northern side of the latter creek, being derived either from the wide belt, which was located on the summit of the Razorback Ridge, or from a continuation of that belt which may underlie this *débris*.

### (d.) *Griffin Creek Area.*

Near the head of Griffin Creek several prominent bands of Pounamu rocks appear. Perhaps the most important of these is the one which outcrops in Nephrite Creek. The band runs about north-east, inclines to the south-east at an angle of 65°, and has a width of about 100 ft., though in this distance it contains several inclusions of the Arahura schists. On the hanging-wall soft greenish talcose schists associated with narrow lenses of quartzose-micaceous schists appear, in which are occasional lenses of quartz. Under the hanging-wall soft talc rocks appear for 20 ft. or 30 ft., partly hidden by the creek-bed. This talc rock is of various shades of green and grey, and occasionally almost white. In it are segregations of greenstone of various size, chiefly of impure nephrite, but with a fair number of good quality (generally of variety "tangiwai"). The talc is sometimes of good quality (see analysis, No. 1, below), though, as a rule, it is somewhat impure (see analysis, No. 2, below). Analyses of talc and steatite from several localities are here inserted for comparison.

| Locality. | Rocks. | Silica. | Alumina. | Ferric Oxide. | Ferrous Oxide | Magnesia. | Lime. | Soda. | Potash. | Water. | Carbon-dioxide. | Titanic Oxide | Phosphoric Acid. | Manganese Oxide. | Various Accessory Constituents. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Griffin Range, Hokitika area | No. 1—White talcose rock | 59·55 | 1·71 | 2·88 | 0·28 | 30·32 | ... | 0·10 | | ... | ... | Nil | ... | 0·15 | * | 99·83 |
| Ditto ... ... | No. 2—Green talcose rock | 58·35 | 2·42 | 3·92 | 1·15 | 28·97 | ... | 0 21 | | ... | ... | „ | ... | 0·13 | † | 99·93 |
| | Pure talc ... | 63·50 | ... | ... | ... | 31·70 | ... | ... | ... | 4·80 | ... | ... | ... | ... | ... | 100·00 |
| St. Lawrence County, New York | Talc ... | 60·59 | 0·13 | 0·21 | ... | 34·72 | ... | ... | ... | 3·77 | ... | ... | ... | 1·16 | ... | 100·58 |
| Ditto ... ... | „ ... | 62·10 | ... | 1·30 | .. | 32·40 | ... | ... | ... | 2·05 | ... | ... | ... | 2·15 | ... | 100·00 |
| Hewitt Mine, North Carolina | Steatite ... | 61·35 | 4·42 | 1·68 | ... | 26 03 | 0·82 | 0 62 | ... | ... | ... | ... | ... | ... | ... | 100·07 |
| Luzenach, France | „ ... | 61·85 | 2·61 | 0·25 | ... | 34·52 | Trace | 0·17 | | 0 60 | ... | ... | ... | ... | ... | 100 00 |
| Valley of Pignerolles, Italy | „ ... | 60 60 | 0·30 | 0·60 | ... | 35·30 | 0·40 | 2·80 | ... | Not determined | ... | ... | ... | ... | ... | 100 00 |

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* Chromium-oxide = 0·14 ; loss above 108° C. = 4·70.

† Chromium-oxide = 0·28 ; loss above 100° C. = 4·50.

The talc rock is continuous for at least 200 ft. along the line of strike, and apparently extends much farther beneath the *débris*. On the foot-wall side a finely foliated mica schist borders the formation. On this flank the latter consists chiefly of a light buff-coloured serpentine rock, which is weathered the deep-brown colour so characteristic of the Pounamu formation. Inclusions of magnetite-talc schist and of pyrite-carbonate schist are very striking features in this locality.

About half a mile to the north-east of Nephrite Creek a band of Pounamu formation crosses the main part of Griffin Creek. Here the associated Pounamu rocks in general resemble those in Nephrite Creek, and in addition show actinolite rock and segregations of beautiful green foliated talc and carbonate (chiefly dolomite) in the serpentine rocks Inclusions of talc schist occur. Segregations of nephrite are somewhat common, and boulders of this mineral evidently derived from the rock *in situ* are frequently seen in the creek-bed, some being of beautiful deep-green colour and quite pure (variety Pounamu probably).

About 200 yards to the north-west of the Nephrite Creek band, massive, handsome green serpentine rocks of brownish outcrop appear. These have a width of 30 ft., and are apparently continuous for some distance, though the outcrops are only shown at the surface by large boulders, which appear at intervals above the tussock and have apparently been weathered *in situ*. On the ridge to the south-westward of Nephrite Creek the narrow band just described, as well as that of Nephrite Creek, appears, and these seem to unite still further to the south-westward at the head of Cold Creek, as already mentioned in connection with the outcrops of the formation on that creek. Heavy snow on the range at the time when visited prevented a detailed study of these interesting outcrops, but in general their character is much the same as that of the minor band, which, as has been mentioned, lies some 200 yards to the north-west of Nephrite Creek.

About 600 yards to the north-west of Nephrite Creek another band of great prominence appears, and is continuous for over half a mile at least and possibly much farther, though the many isolated outcrops are often difficult to connect. This band forms the *massif* of Mount Griffin. It consists almost entirely of a massive serpentine, sometimes of a rich dark-green colour, again of a light-yellowish grey-green, occasionally spotted with small patches of carbonate which is in places ferriferous. The rock is well jointed, the master joints following the general trend of the band, or about north-eastward. The dip is to the south-eastward at an angle of 60°, though sometimes less. The surface is sometimes pitted by the removal of carbonate, and weathers the usual deep brown. Nephrite is very rare, but veinlets of carbonate are somewhat common, while slickensided surfaces show coarse crystals of various asbestiform magnesian minerals. Analyses were made of the deep-green serpentine rock and of the light greenish-yellow serpentine rock from the locality of Griffin Creek (see table, page 76), together with analyses of dunites and peridotites from various parts of the world, in order to illustrate the mode of origin of the serpentine rocks.

An analysis for the precious metals was made of several small pebbles of the massive serpentine rock from Griffin Creek, the specimens being obtained from about half a mile above the lower gorge. The analysis showed 8 gr. of gold and 7 gr. of silver to the ton.

### *(e.) Taipo Gorge Area.*

The well-known "soapstone" of the Taipo Gorge is an outcrop of the Pounamu formation. The band has a maximum width of about 50 ft. and runs in a direction of about 20° east of north, while it dips in a westerly direction at some 85°. The prevailing rocks consist of talc-carbonate and serpentine-talc-carbonate, which contain lensoid inclusions of highly metamorphic schists. Practically none of the talc is very pure, as it occurs always more or less mixed with carbonate. In general the rock is weathered a dull grey or grey green, though in places it is brownish where the carbonates, generally magnesic, are ferriferous. Some years ago the Taipo

| Locality. | Rocks. | Silica. | Alumina. | Ferric Oxide. | Ferrous Oxide. | Magnesia. | Lime. | Soda. | Potash. | Water. | Carbon-dioxide. | Titanic Oxide. | Phosphoric Acid. | Manganosis Oxide. | Various Accessory Constituents. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Griffin Creek, Hokitika area, New Zealand | Dark-green serpentine rock | 41·67 | 0·35 | 0·91 | 5·02 | 39·28 | Nil | 0·19 | | ... | Nil | 0·10 | ... | 0·14 | Loss above 100° C. = 12·02; chromium-oxide = 0·36 | 100·04 (*a*) |
| Griffin Creek, Hokitika area, New Zealand | Yellowish-green serpentine rock | 42·30 | 0·88 | 0·49 | 5·54 | 38·20 | Nil | 0·12 | | ... | Nil | 0·10 | Not determined | 0·21 | Loss above 100° C. = 11·45; chromium-oxide = 0·40 | 99·69 (*a*) |
| Corundum Hill, Mason County, South Carolina, U.S.A. | Dunite* ... | 40·11 | 0·88 | 1·20 | 6·09 | 48·58 | ... | ... | ... | 2·74 | ... | ... | ... | ... | $Cr_2O_8$ = 0·18; chromite = 0·56 | 100·34 |
| Tulameen River, British Columbia, Canada | Dunite† ... | 38·40 | 0·29 | 3·42 | 6·69 | 45·23 | 0·35 | 0·08 | | 4·35 | 1·10 | None | Trace | 0·24 | S = 0·06 ...<br>$Cr_2O_8$ = 0·07<br>NiO = 0·10 | 100·38 (*b*) |
| Dun Mountain, New Zealand | Dunite‡ ... | 42·80 | ... | ... | 9·40 | 47·38 | ... | Trace | ... | 0·57 | ... | ... | ... | ... | NiO trace ... | 100·15 |
| Olivine Range, New Zealand | Peridotite§ | 39·99 | 3·55 | ... | 8·56 | 41·26 | 4·19 | ... | ... | 2·07 | ... | ... | ... | Trace | $Cr_2O_3$ trace ... | 99·62 |
| Laurel Creek, Rabun County, Georgia, U.S.A. | Dunite‖ ... | 42·71 | 0·70 | Not determined | 6·83 | 41·18 | Not determined | Not determined | Not det. | 8·38 | ... | ... | ... | 0·09 | $Cr_2O_3$ trace ...<br>NiO = 0·32 | 100·21 (*b*) |
| Solwa Supreya. Ural Mountains, Russia | Dunite¶ ... | 38·72 | 2·55 | 4·50 | 3·76 | 41·36 | Not determined | 0·57 | Not det. | 7·70 | ... | ... | ... | ... | ... | 99·16 (*b*) |

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* From an analysis by T. M. Chartard in "Bulletin of United States Geological Survey," No. 42, page 55, 1897. † From "Chemical Analyses of Igneous Rocks," by H. S Washington, in Professional Paper of United States Geological Survey, No. 14, page 369, 1903. ‡ From an analysis by A. Schrotter in a report by F. von Hochstetter in "Geologie von Neu Seeland"; Wein, page 220, 1864. § From an analysis by T. Bateman in a professional paper by G. H. F. Ulrich, "Quarterly Journal Geological Survey," Vol. xlvi, page 629, 1890. ‖ From an analysis by W. H Emerson, given in a paper by F. P. Klug, "Bulletin Geological Survey of Georgia," No. 2, page 81, 1894. ¶ From an analysis by Kekmeyer in a paper by Loewinson-Lessing, Dorpat, 1900, page 166. (*a*) Free from carbonate. (*b*) Not fresh.

Gorge band was staked as a gold claim. The assays are said to have yielded a little gold, but this was probably brought down by the river as alluvium, and caught in the crevices of the soft talcose rock.

### Economic Possibilities of the Pounamu Formation.

The Pounamu formation and the rocks directly associated with it seem to present a number of economic possibilities. The mineral nephrite, which forms the valuable greenstone of commerce, is found *in situ* at the head of Griffin Creek, and to a much lesser extent elsewhere. It is sometimes seen as actual segregations of good quality in the talcose matrix, and there can be no doubt that the numerous boulders lying on the surface were derived from the talcose rock near at hand. Very probably considerable nephrite could be obtained in the Griffin Creek locality. Most likely further investigation in other parts of the Pounamu formation within the Hokitika area will reveal new localities for this interesting and beautiful mineral.

Precious rubies are found in the drift near Kanieri, at Rimu, at Kanieri Forks, and elsewhere. The mineral usually occurs in a dark-green matrix composed chiefly of chrome mica and altered olivine, the rubies and matrix forming a very beautiful rock known to the miners as "ruby rock." Some years ago a ruby of singular beauty and of large size was found in a sluicing claim near Kanieri. It is said that the gem would have been of great value had it not been fractured. Rubies were observed by the writers in boulders of muscovite-serpentine rock in Olderog's Creek. These boulders almost certainly descended from the lofty cliffs of McArthur Crags, where the rock is probably to be found *in situ*. There can be no doubt that the ruby rock found in the Kanieri drift came from the Pounamu belt, though it is hardly likely to have been derived from the area now being described, since most of the *débris* at Kanieri was probably brought down chiefly by the Hokitika Glacier.

Talc has many uses in the arts and in commerce, these varying according to its purity and physical characteristics. When very pure it is used for paper-manufacture. It is also used as an abrasive in soap-manufacture, as a dressing for fine leathers, to a certain extent in the manufacture of shoes and gloves, and for crayons and slate-pencils. Impure talc or soapstone is used in thin slabs for sinks, stationary wash-tubs, and electric switchboards. There are deposits of talc of various degrees of purity in Nephrite Creek, in the Griffin Creek locality.

Small bunches of cupriferous pyrites occur on McArthur Crags, but are economically unimportant. In his report on "Geological Explorations in the Northern Part of Westland," published in 1893, Mr. A. McKay describes an occurrence of cupriferous pyrites from near Clarke's Creek as follows: "Samples of cupriferous slate from the contact of the olivine belt with the underlying schists yielded as much as 9 per cent. of copper; and, as this is a rock impregnated with copper and not a mineral vein, and of considerable thickness, portions of it may be payable to work."

The massive serpentine rocks of various shades of green polish beautifully, especially when pure, and give a very handsome stone eminently suitable for ornamental purposes, for façades of buildings, table-tops, mantelpieces, &c. The rock polishes easily owing to the fact that it is fairly soft, and it could be easily quarried. Serpentine rocks of great beauty occur in the Griffin Creek belt and in the Rough Wainihinihi belts of the Pounamu formation. According to Mr. McKay they are also to be found on the slopes of the Bald Range, between the Taipo Gorge and Rocky Point, in the valley of the Teremakau.*

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* Mining Reports, 1893, C.-3, p. 172.

# CHAPTER IX.

## KOITERANGI SERIES.

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### Age and Correlation.

All the rocks of the coal series occurring in Westland have heretofore been referred by the Geological Survey to either a Cretaceous or Cretaceo-tertiary age.* Professor James Park, in a paper contributed to the Mining and Metallurgical Society of London, in 1900, questions the use of this term "Cretaceo-tertiary," which he holds has arisen owing to the seemingly stratigraphical conformity existing in certain localities in the South Island between the Oamaru stone (calcareous sandstone or limestone) containing "Tertiary forms only," and the Amuri limestone containing "Secondary forms only." Within the area covered by this bulletin only the remnants of these formerly widespread rocks occur, and as no palæontological evidence of any value was obtained by the writers an opinion cannot at present be expressed by them on this debatable question. These rocks have therefore been tentatively grouped together under the general name of "Koiterangi series." In the localities observed the beds are separated by a great unconformity from the rocks of the Kanieri series, but have been involved with the older rock-masses in the great orogenic movement of Post-Cretaceous times, which has been referred to in another part of this bulletin.

### Distribution of the Koiterangi Series.

The Koiterangi series has development in two distinct localities within the boundaries of the Hokitika Sheet—namely, at Koiterangi Hill and at Gentle Annie Hill. Koiterangi rises as an isolated mountain to a height of 1,841 ft., covers an area of some 2,000 acres—part of which is outside the limits of the Hokitika Sheet—and is surrounded by the recent deposits of the plain of Kokatahi, with a general level of 130 ft. above sea-level. With this area is also to be connected a small outlier of limestone rising as a ridge 50 ft. high above the plain, about a mile to the north-eastward of Koiterangi. At Gentle Annie the series covers an area approximately estimated at 275 acres, with an average elevation above sea-level of 1,050 ft. The outcrops afforded by the track-cuttings and the small creeks scoring the hillside are poor, but the boundaries delineated on the maps will be found approximately correct.

### Special Areas.

#### *Koiterangi (or Camel Back).*

With the exception of the western flank, where the rocks of the Kanieri series outcrop and attain a maximum elevation of 1,118 ft., as well as a small area forming the middle knoll, rising to a height of 1,660 ft. above sea-level, and due to the existence of a cap of hard olivine basalt, which has been here extruded, the whole mountain-mass is formed of rocks of the coal series. The strata are conformable throughout and overlie unconformably the older grauwackes. In ascending order they are (1) conglomerates; (2) grits, sandstones and shales with coal-seams; (3) calcareous sandstones and limestones.

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* Reports by Mr. A. McKay, C.-13, 1895, Parliamentary Papers of New Zealand.

(1.) The conglomerates have a thickness certainly exceeding 1,000 ft., and probably greater. The coarser constituents consist in the main of fine pebbles, though medium-sized cobbles and large boulders, often subangular, are also present, especially in the lower portion. These are imbedded in a matrix partly arenaceous and partly argillaceous, while iron-oxide ($Fe_2O_3$) is abundant throughout as a cementing material, and imparts its characteristic red colour to the whole mass. The great bulk of the pebbles and boulders consists of grauwackes, while slate and quartz occur to a minor extent, and granite is conspicuous by its absence.

(2.) The grits and coarser sandstones are ferruginous and micaceous, while the softer marly sandstone, which in places may be glauconitic, are associated with the shales and mudstones. The coal which has been discovered in this strata is, as the analysis will show, of inferior quality. Outcrops, which are probably to be referred to the same seam, were located at a point, having an elevation of 1,510 ft., about 300 yards to the south-west of the summit of the mountain, and again at a point, having an elevation of 1,000 ft., half a mile east-north-east of the summit. At the former locality the seam referred to is 6½ ft. thick, with a dip of 17° to the north-eastward. The upper 18 in. is of slightly better quality than the remainder, which consists in great part of bands of hard carbonaceous mudstone; but even this upper part is rendered of no economic value by the high percentage of ash which it contains. The analyses of representative samples from both the upper and lower portions are respectively as under:—

| | Upper Portion. Per Cent. | Lower Portion. Per Cent. |
|---|---|---|
| Fixed carbon | 30·8 | 22·7 |
| Hydrocarbons | 37·7 | 28·9 |
| Water | 3·6 | 2·9 |
| Ash | 27·9 | 45·5 |
| | 100·0 | 100·0 |
| Total sulphur | 5·07 | 4·62 |

Higher up in the same horizon as this seam, bands consisting of carbonaceous shales or mudstones with impure coaly partings occur. At the outcrop, referred to as lying to the north-east of the summit of the mountain, the seam which dips at an angle of 11° has been driven on for about 14 ft., and here 16 in. of crushed coal, of slightly better quality than the above, and accompanied by carbonaceous bands, is exposed resting on a sandstone floor. An analysis of the crushed coal from the seam in this drive is as under:—

| | Per Cent. |
|---|---|
| Fixed carbon | 41·5 |
| Hydrocarbons | 38·8 |
| Water | 5·4 |
| Ash | 14·3 |
| | 100·0 |
| Total sulphur | 5·55 |

The coal burns to a white ash, and when heated in a closed vessel cakes very slightly.

The clays in association with the coal-seams were analysed in the hope that they might be utilised as fireclay, but the large amounts of iron-oxide, soda, and potash render the material useless for this purpose.

| | Per Cent. |
|---|---|
| Silica | 60·3 |
| Alumina | 17·9 |
| Iron-oxides | 6·4 |
| Titanium-oxide | 0·9 |
| Lime | 0·8 |
| Magnesia | 1·8 |
| Soda and potash ($Na_2O$, $K_2O$) | 3·1 |
| Organic matter and water | 8·8 |
| | 100·0 |

Most of the carbonaceous bands referred to contain numerous carbonised plant-remains, but these are poorly preserved and of no value for palæontological identification.

(3.) The limestone and calcareous sandstones mark the closing beds of the series, and are in all about 250 ft. in thickness. These have been correlated with the Cobden limestone of Greymouth by Mr. A. McKay,* who remarks, " This limestone is in some respects very similar to the Whangarei limestone, or the lower part of Abbey Rocks limestone in the southern part of Westland." This massive limestone has a dark bluish-grey colour, and, although partly crystalline, is so finely textured as to present a somewhat earthy appearance. Although in places of very fair quality, the rock over a portion of the area is very impure, and should be classed rather as a calcareous sandstone. Analyses of the rock of better quality and of the lime obtained commercially from " burning " the same are as under:—

| | Arenaceous Limestone.<br>Per Cent. | Impure Lime.<br>Per Cent. |
|---|---|---|
| Silica | 24·0 | 25·2 |
| Alumina | 3·5 | 5·0 |
| Iron-oxides | 1·8 | 2·0 |
| Titanium-oxide | 0·1 | 0·2 |
| Lime | 39·4 | 45·4 |
| Magnesia | 1·2 | 1·3 |
| Carbonic anhydride ($CO_2$) | 30·0 | 10·8 |
| Water of hydration | ... | 10·1 |
| | 100·0 | 100·0 |

Fossils have been observed in this rock only at one locality—namely, near McArthur limekiln; they consist of numerous casts of fucoids (seaweeds) and certain bivalves, which unfortunately are too poorly preserved to admit of identification.

The disposition of the strata forming this mountain and the structural features, as inferred from the somewhat scanty data afforded by a few small outcrops, is sufficiently well indicated on the maps and sections accompanying this report. On the whole the strata are uniformly inclined at comparatively low angles, but the abrupt changes in the strike and dip and a consideration of topographical features suggest considerable faulting.

The results of investigation and analyses prove that the economic value attaching to the coal-seams of the Koiterangi area must be pronounced as small, but prospecting might with advantage be carried out to ascertain if other seams existed. The coal-measures are over a greater portion of the area water-free, comparatively limited in vertical extent, and included between easily recognisable bedded rocks, so that further exploitation should present little difficulty.

The limestone is very close-grained and tough, and would be of value for building purposes. The impure lime obtained from it is of use as a fertiliser, as whitewash, and for various other purposes.

### *Gentle Annie Area.*

The sequence of strata at Gentle Annie is not nearly so complete as at Koiterangi, the conglomerate at the base being but poorly represented, while the closing members—limestone and calcareous sandstone—are absent. The beds here are disposed as a small basin-like mass, and the dip where observable is at high angles towards a centre. A thin bed of rusty, pebbly conglomerate, which rests unconformably on the basement rock and may probably be correlated with the heavy conglomerate of Koiterangi, is succeeded by ferruginous and micaceous sandstones and grits, fine-grained dark-greenish argillaceous sandstones, and shales with coal-seams.

Two seams of coal separated by only 10 ft. of sandstone, more or less carbonaceous, are well exposed in old mine-workings, and rather poorly on the surface. The strike of these two bands is in agreement—north 34° east—but the dips vary from 75° eastward in the upper or easterly seam to 45° eastward in the lower or most westerly seam. The floor, or, rather, the foot-wall country on which these highly inclined seams rest is a sandstone, more or less carbonaceous in the vicinity of the coal, while dark-coloured arenaceous shales, which in certain localities give place to sandstone, constitute the overburden.

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* C.-3, 1893, Parliamentary Reports of New Zealand.

No. 1, or westerly, seam has a width of 4 ft., but owing to the presence of banded argillaceous and sandy layers only 2 ft. 9 in. can be regarded as coal, and this itself, as the following analysis shows, is of very poor quality:—

| | Per Cent. |
|---|---|
| Fixed carbon ... ... ... ... ... ... ... | 27·90 |
| Hydrocarbons ... ... ... ... ... ... ... | 31·53 |
| Water ... ... ... ... ... ... ... | 0·67 |
| Ash ... ... ... ... ... ... ... | 39·90 |
| | 100·00 |
| Total sulphur ... ... ... ... ... ... | 1·31 |

*Remarks.*—This burns with difficulty, owing to the enormous amount of ash which it contains.

No. 2, or easterly, seam is at least 5 ft. 6 in. in thickness, but having been involved with the strata in the great orogenic movements the coal is much crushed and slickensided, and towards the floor is of low grade owing to the inclusion of sandy and argillaceous bands. An analysis of a fair sample of this coal is as under:—

| | Per Cent. |
|---|---|
| Fixed carbon ... ... ... ... ... ... ... | 48·00 |
| Hydrocarbons ... ... ... ... ... ... ... | 35·27 |
| Water ... ... ... ... ... ... ... | 1·03 |
| Ash ... ... ... ... ... ... ... | 15·70 |
| | 100·00 |
| Total sulphur ... ... ... ... ... ... | 2·60 |

*Remarks.*—This is a highly bituminous coal, which burns well in spite of the large amount of ash it contains. When heated in a closed vessel it forms a very bulky porous coke resembling that from the Mine Creek, Westport.

The Gentle Annie coal-area was the subject of a special report by Mr. W. D. Campbell in 1877,* as the result of which Sir James Hector stated that "there appears to be no fresh evidence of the existence of workable coal-seams in the Kanieri district which will warrant further expenditure for explorations by boring or sinking."

From a consideration of the character of the coal, the high angle at which it is inclined, and the limited area of the coal-measure strata, the writers concur in this opinion, but consider that the coal already opened up would have some value if required for fuel in the immediate vicinity.

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* New Zealand Geological Reports, 1877.

# CHAPTER X.

## THE BASIC DYKES OF THE HOKITIKA SHEET.

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### CONTENT OF THE BASIC DYKES.

In marked mineralogical and chemical contrast to the acidic Tuhua intrusives are the widely scattered, narrow basic dykes. These dykes consist of pyroxene camptonite, hornblende camptonite, hornblende porphyrite, pyroxene porphyrite, diabase, and augite diorite. At one point in the district these basic igneous rocks spread out on the surface, giving true volcanic lavas of the olivine basalt type.

### GENERAL DISTRIBUTION OF THE BASIC DYKES.

The basic dykes have a wide though inextensive distribution in the area now being considered So far as is known they are always associated with the rocks of the Tuhua formation, with the exception of one point—the middle knob of Koiterangi Hill—where the effusion of olivine basalt already mentioned appears, overlying unconformably the lower part of the Koiterangi series. The top of the Hohonu Range and its southern slopes are seamed in places with narrow basic dykes. They outcrop at the base of Mount Turiwhate along the Christchurch Road, on the summit of Mount Turiwhate, and along its southern side around Island Hill, on the eastern slopes of Mount Graham, and along the Humphrey's Gully Water-race east of the crossing of Stony Creek.

The age of the basic dykes can be fixed with some fair accuracy. The effusion of olivine basalt on Koiterangi Hill was poured out on a denuded surface of the Koiterangi series, and hence is of more recent age than these rocks. Owing to lithological similarity it is supposed that this extrusion is of the same age as the various basic dykes which cut the granites. It is very probable that the basic igneous rocks belong to the early or middle Tertiary period.

### PETROLOGY OF THE BASIC DYKES.

It has been mentioned that the basic dykes and volcanics comprise the following varieties: Pyroxene camptonite, hornblende camptonite, hornblende porphyrite, pyroxene porphyrite, diabase, augite diorite, and olivine basalt. Megascopically the pyroxene camptonite exhibits a dark-greyish rock, occasionally rusty on the surface, and rarely with very pronounced phenocrysts of the ferromagnesian minerals visible. Under the microscope the groundmass and phenocrysts are distinct and decided. The groundmass is generally finely holocrystalline, and is chiefly composed of laths of plagioclase and brown hornblende, both in idiomorphic forms and in fine sheaves. Often both hornblende and plagioclase are much altered, the former to zoisite, epidote, and calcite, while the latter is chiefly chloritized. In this groundmass is possibly a little pyroxene and the accessory minerals pyrite, magnetite, and sometimes apatite and ilmenite (altering to leucoxene). The phenocrysts are mainly of a light-coloured pyroxene, which is probably augite. The large pyroxenes are sometimes rendered pœcilitic by the presence of many small idiomorphic individuals of hornblende. Owing to the fact that the prevailing phenocryst is pyroxene, the rock is called a pyroxene camptonite. Hornblende camptonite differs from pyroxene camptonite only in the presence of hornblende as the principal phenocryst instead of pyroxene. Camptonite dykes occur on the summit of Mount Turiwhate, and in the prominent outcrops of the Tuhua rocks on the Christchurch Road, a short distance west of Fitzgerald's.

With the loss of the sharp idiomorphic habit of the ferro-magnesian minerals in the groundmass, and with the growth of phenocrysts of feldspar, the camptonites grade into porphyrites, and cease to be true lamprophyres. The porphyrites are either hornblende porphyrite or pyroxene porphyrite, depending on which of the two minerals hornblende or pyroxene prevails. The diabases differ from the pyroxene porphyrites in being non-porphyritic, while the augite diorite differs from the hornblende porphyrite in being non-porphyritic, and in its coarse texture. In the hand-specimen the porphyrites are dark-greyish rocks, with a generally fine-grained groundmass, in which are imbedded relatively large phenocrysts of whitish plagioclase and pyroxene or hornblende. Beneath the microscope the groundmass is made up of a matte composed of laths of labradorite, with irregular hornblendes or colourless pyroxenes. Both the feldspar and the ferro-magnesian minerals are often much decomposed with the formation of calcite, epidote, and chlorite. The phenocrysts are of labradorite and of either pyroxene or hornblende, depending on whether the rock is to be classed as pyroxene porphyrite or hornblende porphyrite. In the more weathered varieties of porphyrite the original ferro-magnesian minerals are replaced by pseudomorphs of chlorite, while ilmenite which is occasionally present is altered to leucoxene. The porphyrites are among the most common of the basic dykes. They are found on Martin Creek, on the Humphrey's Gully Water-race, and elsewhere. A transition rock between porphyrite and camptonite is one in which the groundmass is partly pandiomorphic and partly allotriomorphic, and in which phenocrysts of both labradorite and either or both pyroxene and hornblende appear. Dykes of this character occur close to others of true porphyrite on Martin Creek.

The diabases are in general slightly more coarse-grained than the porphyrites, and the constituent minerals are fairly visible megascopically. The rock consists essentially of pyroxene and labradorite, with various accessories. The augite diorites are medium- to coarse-grained holocrystalline non-porphyritic rocks, in which the principal constituents are plainly visible in the field. Under the microscope the rock exhibits the original minerals--hornblende, pyroxene, and plagioclase—in allotriomorphic construction, with which occur idiomorphic individuals of pyrite, and hexagonal grains and prisms of apatite. Secondary chlorite, calcite, and epidote are common. A dyke of augite diorite was observed in one locality only, in the remarkable complex of Tuhua rocks on the Christchurch Road, a short distance west of Fitzgerald's.

The olivine basalt from the summit of Koiterangi Hill forms megascopically a rock of considerable beauty. The groundmass, which predominates, is almost black and very fine-grained, and in it are inserted numerous glassy deep-green olivine phenocrysts, ½ in, or even more, in length. In places the rock is weathered to a dark reddish-brown. Under the microscope the phenocrysts stand out with great relief from the groundmass. The latter is hemicrystalline, and is composed partly of a very fine-grained, almost microlitic matte of plagioclase and tiny needles of ferro-magnesian minerals apparently pyroxene (as judged from extinction angles, relief, &c.), and partly of a dark basic isotropic glass. Through this groundmass are disseminated innumerable small irregular grains, regular crystals of magnetite and small olivines just beginning to serpentinise. The large phenocrysts of olivine show serpentinisation only along the cracks and around the edges. They are occasionally beautifully zoned.

### WIDTH AND SPECIAL AREAS OF THE BASIC DYKES.

The dykes are nearly all very narrow. Those seen on the eastern slopes of Mount Graham are only a few inches wide, and are almost entirely decomposed on the surface to the consistency of laterite. The two dykes of porphyrite along the Humphrey's Gully Water-race have a maximum width of about 4 ft. The widest dyke in Martin Creek, which is of porphyrite, has a width of 7 ft., while the greatest lateral dimension of any basic dyke on Mount Turiwhate is some 10 ft. The dykes along the Christchurch Road, west of Fitzgerald's, are nearly all narrow, though one of augite diorite is of considerable width. They present a wide textural range, varying from fine-grained camptonites to the coarsely crystalline augite-diorite dyke. The narrow basic dykes are sometimes faulted, and dip with every inclination from horizontality to verticality. The dyke of augite diorite is not under 35 ft. in width, and dips at about 88° to the eastward. It is in places much decomposed, and exhibits the interesting phenomenon of spheroidal weathering. Owing to the distinct textural variation of this rock from the other observed outcrops of the black dykes it was at first supposed to be of different age from the rest of the dykes, but the variation is apparently only one of crystallization, which would naturally be slower than in the narrower dykes close to the cooling surface of the intruded rocks. The dykes on the summit of the Hohonu Ranges vary from 2 ft. to 4 ft. 6 in. in width.

Much the most interesting outcrop of the basic igneous rocks is that of the effusion of olivine basalt, on the middle knob of that petrographically extraordinary mountain—Koiterangi Hill. As already mentioned the rock rests on a denuded surface of the coal-measures and is a true extrusion, which probably rose to the surface through a narrow neck. The outcrops are small, and appear *in situ* at one or two places only; but, judging by the frequency of angular detritus, evidently derived from rock in place, the area covered by the volcanic rock on the surface cannot be less than a quarter of a mile in every direction. At the contact of the basalt with the underlying conglomerate much red clay is developed from the decay of the basalt, which is much decomposed for some feet from the junction. This contact appears in a low cliff about 20 yards south of the ridge which runs north-west from the middle knob of Koiterangi. About 5 or 6 yards west of the contact the unweathered basalt is well exposed. The olivine phenocrysts of the basalt are of great beauty, clear and fresh, and if they could be easily removed from the matrix in which they lie they would be almost suitable for gems.

# CHAPTER XI.

## LATER TERTIARY, PLEISTOCENE, AND RECENT ROCKS.

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### General Description of the Several Formations.

In the chapter on geological history it has been mentioned that the Blue Bottom is supposed to be a deposit consisting chiefly of rock-flour brought down by various rivers from an elevated interior in which glacial excavation was proceeding. This supposition is based on the nature of the clays themselves, and because of the occurrence within them of striated boulders of rocks lithologically identical with those occurring in the mountainous hinterland. The clays of the Blue Bottom, which are, as judged by palæontological evidence, of Miocene age, at least in their lower exposures, grade upwards into indurated sands with thin gravel layers, which are known locally at Kanieri as the "Brighton Bottom." Inland these beds pass into the Humphrey's Gully beds, which have been tentatively classified as Pliocene, but may be more recent. It is to be distinctly understood that while the Humphrey's Gully gravels were being deposited near the edge of the old land, sands were being laid down to the westward, and still farther out to sea the upper clays and sands of the Blue Bottom proper were forming, all being contemporaneous. Thus it is that while we get gravels at a certain altitude at Humphrey's Gully, at the same altitude or even higher at Greek's Gully, not more than a mile to the westward, only sandstone with narrow seams of gravel appears.

After the elevation of the land following the deposition of the Humphrey's Gully beds came the great advance of the ice, which in its maximum extension must have been almost continental in its proportions, probably stretching out to sea. Partly in this advance, but mainly while retreating, this great ice sheet laid down immense quantities of irregular unstratified material all over the land and on the sea-bottom of that time when the shore-line was probably farther to the eastward than at present. With the glacial retreat much of the morainic material was deposited so thickly as to form new land, while elsewhere it was reassorted by the sea-waves beneath the water, and laid down where originally transported as faintly stratified beds often of coarse material. These beds were augmented partly by the gravels brought to the sea by the various streams flowing from the edge of the retreating ice, and partly by the actual abrasion by the waves on the cliffs of morainic material bordering the sea. These beds when the land rose became the older marine terraces. Meanwhile fluviatile gravels were being laid down by rivers flowing from the ice-front. It is possible that marine and fluviatile gravels may have been deposited between the time of elevation of the Humphrey's Gully beds and the maximum ice-advance in front of the seaward moving ice.

After well-formed valleys had been incised in the morainic material laid down by the glaciers in their time of maximum advance, and underlain by either the Blue Bottom or the Humphrey's Gully beds, or both, there came on the western side of the mountains at least a second (and possibly a third) minor ice-advance. These glaciers were purely piedmont in character. They descended as far as Kanieri and Woodstock, laying down the moraines near those townships, and possibly those near Kawhaka and elsewhere. During the last ice-advance and since that time there has been continuous marine deposition, and some of these deposits have themselves risen above the sea and been subjected to erosion. Fluviatile sedimentation has also progressed, which has resulted in many terraces along the various rivers and streams.

It will be readily understood from a perusal of this brief description of the origin of the later Tertiary and more recent deposits that it is sometimes exceedingly difficult to discriminate between the various unconsolidated materials. Probably the only real unconformity occurs at the close of the Humphrey's Gully beds, though there is some evidence even there in places that while these beds were being laid down morainic *débris* was also being deposited. It is certain that while the morainic *débris* of the great ice-advance was being scattered irregularly over the country, marine sediments were forming, and probably fluviatile sediments. Similarly, while the moraines of the minor piedmont glaciers were being laid down, later marine and fluviatile deposits were forming.

On the accompanying map the Blue Bottom includes the sandstones which are generally in the higher horizons. The Humphrey's Gully beds, really equivalent in age to the latter, are shown by a conventional design. All marine gravels, later than the Humphrey's Gully beds, up to the present—whether pre-glacial, contemporaneous with the glaciers, or post-glacial—are grouped together indiscriminately. Similarly all unstratified morainic materials, whether of the maximum or minor ice-advance, are classed together, and also all river-formed sediments, though it is to be understood that there are relatively slight differentiations in age. On the accompanying map the marine gravels, morainic material, and fluviatile gravels are shown, like the Humphrey's Gully beds, by conventional designs on top of the general colour for the Blue Bottom, which undoubtedly underlies much of the wide area covered by the various gravels.

Gold ocurs to a very small extent in the Blue Bottom, much more so in the Humphrey's Gully beds, widely distributed, though rarely, if ever, appreciably rich in the morainic material, and in bonanza leads in both the older and more recent marine and fluviatile gravels. Where rich it is always found to be due to a natural concentration of slightly auriferous material by fluviatile or marine action

In Mr. McKay's various reports on Westland he has dealt so fully on the later Tertiary and more recent deposits that the authors of this bulletin feel that they can add little information on this subject. Mr. McKay had exceptional opportunities to study the mode of occurrence of the gold, as he was actually in the area while most of the precious metal was being obtained from the various gravels.

Of course, it is evident that in the reassortment of glacial or morainic material by the sea-waves, or by stream-action, there is every gradation between the heterogenous morainic stuff to the finely and well-assorted fluviatile or marine sediments, and thus we may have fluvio-glacial material, glacio-marine material, &c.

## BLUE BOTTOM FORMATION.

### *Distribution.*

The Blue Bottom is so called because it forms the basement formation of the extensive unconsolidated later Tertiary and more recent deposits of the coastal plain, and consists chiefly of blue clay. It is locally called " Brighton Bottom " at Rimu. Within the Hokitika Sheet it underlies the greater portion of the Kanieri and Mahinapua Survey Districts, and may extend beneath the drift eastward to the lower western flanks of the various mountain outliers between the Hohonu Ranges and Koiterangi Mountain. The most easterly outcrops located are at Gentle Annie, where the formation attains an elevation of 814 ft., and in the bed of the Arahura River, near the junction of Smith's Creek, where it underlies a high vertical face of stratified fluviatile gravels. Westward it extends to the coast-line, but is here almost invariably concealed by morainic, fluviatile, and marine material. Exposures, however, are seen at the base of a terrace, fringed by low sandhills, lying only some 35 chains from the present coast-line, at a point a mile south of the mouth of the Hokitika River.

The marine clays and sands which constitute the Blue Bottom are stratified, in general horizontal or inclined at very low angles to the westward; but approaching the eastern limits of the formation signs of warping are apparent, the beds dipping at fairly high angles to the westward. This warping is indicative of the latest orogenic movement (Post-Miocene), of which the region gives evidence. Local crenelation and corrugation due to ice-pressure are frequently noticeable. In the vicinity of Fox's this formation is found at an elevation of about 1,000 ft. above sea-level, and dipping to the eastward generally at angles of about 15°, but in places as high as 30°. When sandy material or cobbles occur the stratification is more apparent than in the homogenous clays, as the sand forms well-marked laminæ, and the cobbles are in general alignment.

Not infrequently in the upper portions of the Blue Bottom isolated erratics occur. Many of these boulders are fairly well rounded, while others are sharply angular and often present knife-like edges. Among them are representatives of all types of rocks occurring in the mountainous country of the Hokitika Sheet, even of the Pounamu formation, and some of the most resistent of these, as already mentioned in this chapter, show deep glacial striæ.

The basement rock of the coastal plain upon which the Blue Bottom rests has never yet been reached in connection with any of the mining operations, but a bore sunk at Kanieri to a depth of 400 ft. was still penetrating these marine clays when the work was abandoned, and it is therefore certain that they attain a very considerable thickness, probably exceeding 1,200 ft. The surface of the formation presents many irregularities, due chiefly to fluviatile and glacial erosion. The consolidated clays offer considerable resistance to weathering agencies, and where incised by river-erosion they sometimes present vertical faces many feet in height, and some of the minor streams run in deep gorges eroded in this material.

### *Lithology of the Blue Bottom.*

The lower part of the Blue Bottom consists almost entirely of marine clays of bluish-grey colour. The mineral constituents of these clays are in an exceedingly fine state of division, and when dry the disintegrated mass yields an almost impalpable powder, which again on being moistened with water becomes thoroughly plastic. Frequently the clays contain concretions which are generally spheroidal, but occasionally take the form of perfectly shaped circular discs, flat-oval in cross-section and with well-rounded edges These concretions sometimes become thoroughly indurated to a compact greyish-coloured shale, which glistens with minute scales of mica. The clays on weathering assume a brownish colour, due to the oxidation of the ferrous iron, but this is more apparent where the beds are rendered porous by the admixture of fine sandy material. Under the microscope the clays consist principally of quartz and feldspathic material with a minor proportion of mica, glauconite, and some unidentifiable minerals, all in an exceedingly fine state of division. In addition to these minerals minute sponge or foraminiferal spicules occur. A chemical anaylsis of two fair samples of these clays is as under:—

| | No. 1.<br>Per Cent. | No. 2.<br>Per Cent. |
|---|---|---|
| Silica ... ... ... ... ... | 57·05 | 60·50 |
| Alumina ... ... ... ... | 22·40 | 20·04 |
| Iron-oxides ... ... ... | 6·56 | 6·60 |
| Lime ... ... ... ... ... | 1·80 | 2·70 |
| Magnesia ... ... ... ... | 1·90 | 1·01 |
| Soda and potash ... ... ... ... | 6·60 | 6·06 |
| Water and organic matter ... ... ... | 3·69 | 3·09 |
| | 100·00 | 100·00 |

The clays of the Blue Bottom grade upward into hardened sands, which sometimes contain thin pebbly layers. The Brighton Bottom at Kanieri consists almost entirely of sandstone, as do the highest exposures at Greek's Gully, Fox's Gully, and elsewhere. Some of the gravel layers are interesting. One particular layer in the upper exposures of the formation near Bluespur contains boulders 1 ft. in diameter, consisting of grauwackes, granite, gneiss, &c.

### *Age of the Blue Bottom.*

The marine clays of the Blue Bottom formation are in many localities abundantly fossiliferous. The fossil fauna contained has already been determined by the New Zealand Geological Survey, and includes many well-known forms, among which the following may be mentioned: *Cerithium rugatum, Voluta pacifica, Dosinea grayi, Natica ovata, Turritella ornata, Dentalium solidum, Panopæa zealandica, Struthiolaria papulosa, Buccinum robinsoni, Ancillaria hebera, Dentalium giganteum, Struthiolaria cincta, Cucullæa ponderosa, Cucullæa alta, Limopsis insolita.* From the fossils above enumerated, in conjunction with numerous others, the age of the Blue Bottom formation has been regarded as Miocene. The Pliocene mollusca is also well represented, and in this connection it may be mentioned that Professor Hutton considered that 64 per cent. of the New Zealand Pliocene mollusca are also found in Miocene rocks.

### *Economic Possibilities of the Blue Bottom.*

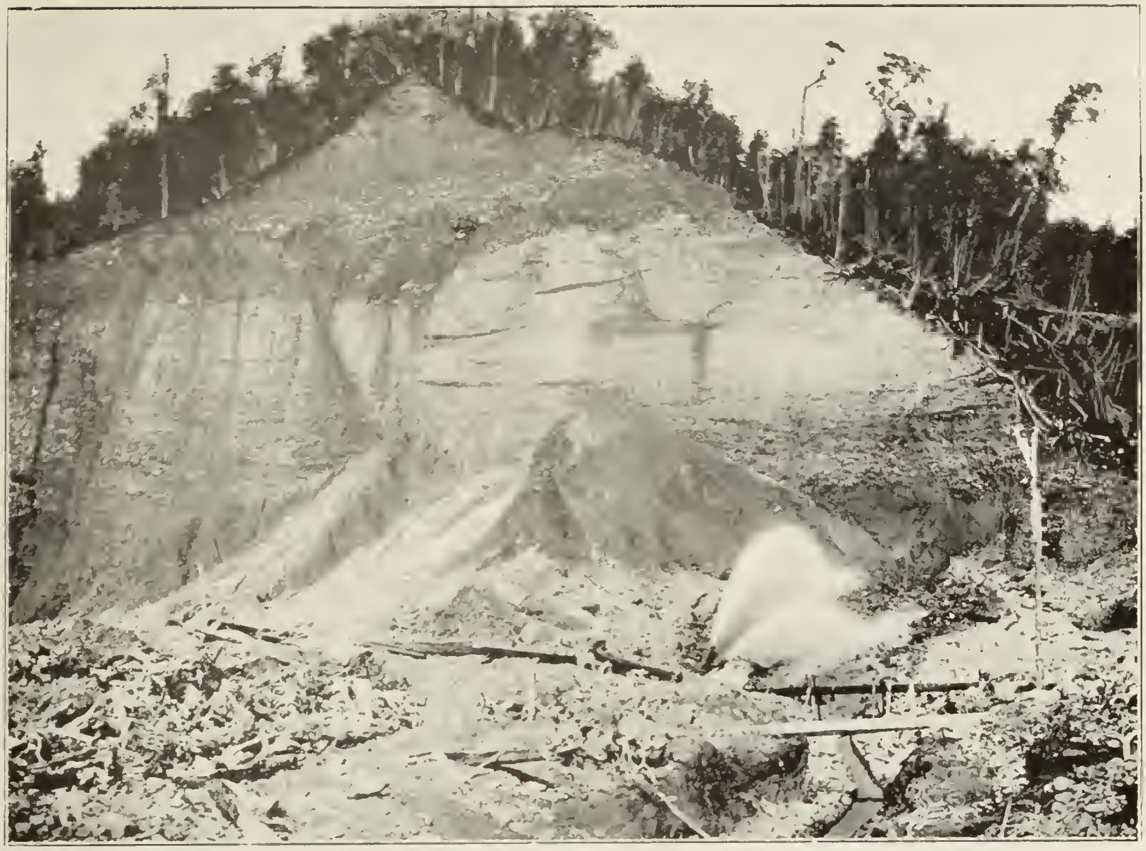
The results of the chemical analyses already quoted indicate that the clays of the Blue Bottom are suitable for brick-making. This fact has already been recognised, and bricks of good quality are now being manufactured near Greymouth from a weathered product of the Blue Bottom. The high percentage of iron renders the clays in general unsuitable for the manufacture of pottery. Since these clays of the Blue Bottom represent sediments derived from the rock-masses, which also gave origin to the coarser *débris* forming the extensive gold-bearing drifts, it might be expected that the Blue Bottom itself should be to some extent auriferous. Accurate analyses made of fairly large quantities, which were selected with care and judgment, show that they do carry small amounts of gold, and in one case a minute amount of floured gold could be detected by careful dish concentration. From the point of view of their gold-content, it is unlikely that these clays will ever be found of economic value, as they have never been subjected to the several reconcentrations which have rendered the coarser rock *débris* payable, nor from their plastic nature would they be readily amenable to mechanical or chemical methods of treatment.

## HUMPHREY'S GULLY BEDS.

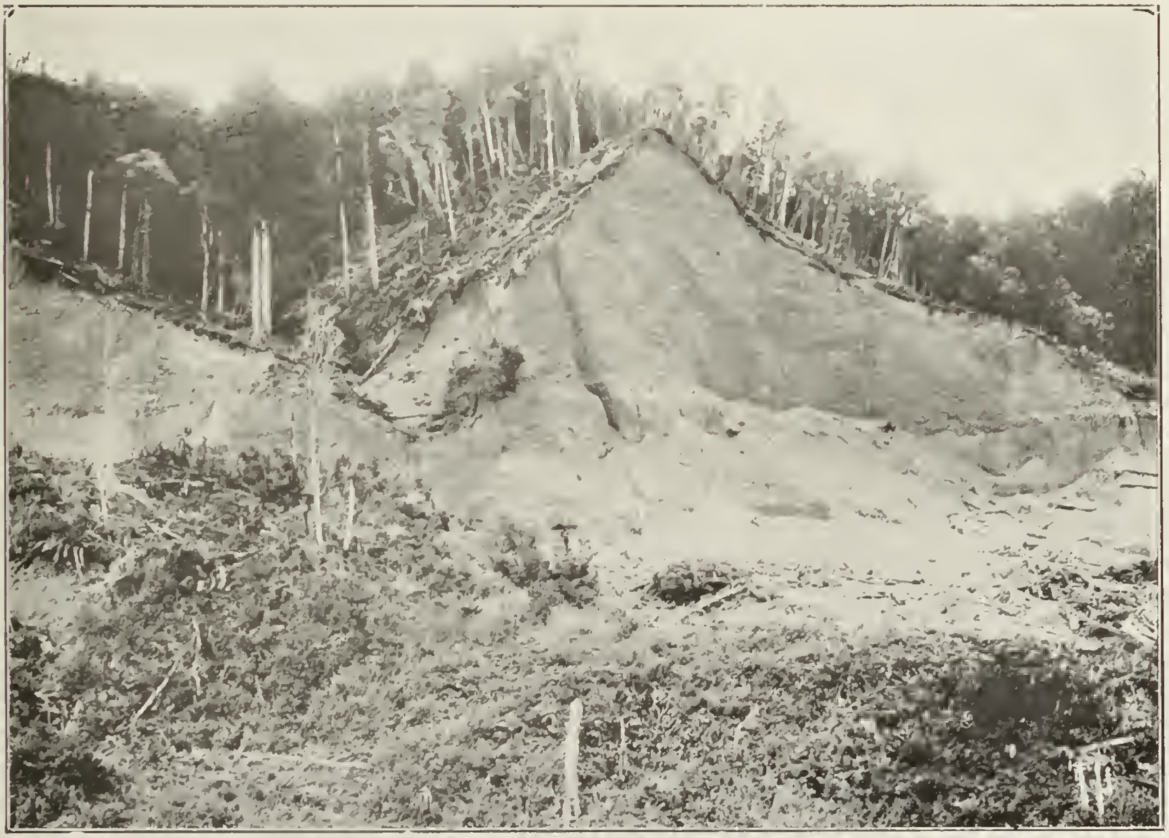
The Humphrey's Gully beds, which consist of very loosely consolidated and more or less stratified conglomerates, are exposed over a very limited area in the Hokitika Sheet, but concealed beneath the morainic material and other deposits they probably have a somewhat greater extension. These beds are typically developed at Humphrey's Gully and in the adjoining hills. Certain other minor areas possibly should be correlated with the Humphrey's Gully beds, but it has been found almost impossible to distinguish them with certainty, and they may more probably belong to the post-glacial fluviatile gravels, or possibly even to pre-glacial fluviatile gravels, deposited after the elevation of the Humphrey's Gully beds.

### *Structure and Lithological Characters.*

The Humphrey's Gully gravels consist of well-rounded and frequently flattened cobbles, averaging a few inches in diameter, of much finer gravel, sand, and a minor amount of argillaceous matter. Beds of coarser and of finer gravels are interstratified, some of the latter consisting



THE HUMPHREY'S GULLY BEDS, OVERLAIN UNCOMFORMABLY BY MORAINIC MATERIALS.



THE HUMPHREY'S GULLY BEDS, NEAR HUMPHREY'S GULLY.

almost entirely of sand. Stratification is obscure in places, and lensoid and false bedding are both common. The larger cobbles are composed chiefly of ferruginously stained grauwacke, while mica schists, quartz-mica schists, granitic rocks, argillite, and quartz also contribute to the formation. The Humphrey's Gully gravels are characterized by their prevailing rusty, brownish-grey colour, while lensoid portions cemented by iron-oxide are also evident. Small concretions, popularly known as "Maori stones" on account of their high specific gravity, are frequently met with in the concentrates derived from these gravels. A chemical analysis of one of these concretions shows the following composition:—

| | Per Cent. |
|---|---|
| Silica | 40·65 |
| Alumina | 20·29 |
| Iron-oxide | 27·85 |
| Manganese-oxide | 3·16 |
| Lime | 4·00 |
| Magnesia | 0·36 |
| Potash | 0·36 |
| Soda | 0·40 |
| Moisture and organic matter | 1·73 |
| $CO_2$ | 1·20 |
| | 100·00 |

### *Special Areas.*

*Humphrey's Gully.*—The most extensive hydraulic-sluicing operations at present being carried on within the Hokitika area are at Humphrey's Gully, where there are large gravel-deposits of the formation under review. The working-faces are almost vertical, and afford a good section of the gravels and their relations to the underlying and overlying deposits. The underlying clays of the Blue Bottom form a good working basement for sluicing operations. Above these the stratified Humphrey's Gully gravels rise as vertical faces to heights varying from 250 ft. to 500 ft., and are overlain by at least 90 ft. of morainic *débris*. The maximum elevation of the stratified gravels above sea-level at this locality is about 925 ft.

No systematic tests appear to have been made as to whether any particular horizons of the formation are more auriferous than others, but it is generally considered that the layers of heavier material contain most gold. No records have been kept of the amount of gravel sluiced for the gold recovered, so unfortunately the average value per cubic yard is not available. The amount of gold obtained from the Humphrey's Gully claim for the period of twenty-two years ending December, 1905, totals 12,339 oz., valued at £47,956, the maximum return for any one year (1904) being £4,790. The gold of Humphrey's Gully is for the most part very fine.

## MORAINIC MATERIAL.

The morainic material consists of unstratified boulder clays, unstratified hard-pans, and very minor amounts of very vaguely stratified gravels, the first two being laid down actually by the ice, the last being probably the deposit of englacial streams. In the boulder clay the matrix is chiefly argillaceous, whereas in the hard-pan it is arenaceous, and occasionally somewhat ferruginous. In the boulder clays and hard-pans fragments occur of any size from those hardly distinguishable from the matrix to others weighing hundreds of tons. The boulders are the erratic equivalents of all the rocks at present seen in the interior, with grauwackes and granite predominating. Nearly all the morainic material is auriferous, though not payably so, except where reassorted more or less by rivers when it becomes fluvio-glacial, or except perhaps in rare instances in the material deposited by the englacial streams.

The distribution of the morainic material is very general throughout the area covered by the coastal plain. It forms the topmost exposures on the Humphrey's Gully and Fox's Gully

Ranges, and covers the country from Kawhaka northward to the Teremakau River. The rounded knolls behind the Township of Kanieri and near Woodstock are of this material, which also covers most of the country northward from Kanieri Forks to Lake Kanieri, and beyond to Milltown. Morainic material surrounds the base of Mount Tuhua, Mount Graham, Conical Hill, and Gentle Annie Hill, and forms much of the main part of the Bluebottle Terrace, though a portion is more correctly considered as fluvio-glacial. The many low ridges surmounting the country southward from Rimu are of morainic drift, which forms the only visible outcrops to and beyond the southern edge of the Mahinapua district. On the eastern side of the Alps terraces of unstratified morainic material are prominent along the headwaters of the Wilberforce River, and a few small moraines are actually forming at present in some of the tributaries of that stream.

## MARINE GRAVELS.

The marine gravels may in a very general way be divided into the older marine gravels and the modern marine gravels. The latter are the recent gravels close to the present sea-beach, and are probably being added to at present. The older marine gravels, which were probably in part at least forming during the maximum glacial extension and certainly before the last ice-advance, have their principal exposures in the various high terraces facing the present sea-beach, and between that feature and the hills of the Bluespur Range. Not improbably part of the terraces which are considered fluvio-glacial at Rimu and Woodstock are farther to the south-westward really glacio-marine, and of the same age as the older marine terraces. There is, of course, no arbitrary subdivision between the older marine terraces and the comparatively modern terraces, nor between them and the Recent ones, all being formed in succession as the sea retreated. The comparatively modern marine terraces are to be found close to the sea-beach between Lake Mahinapua and the sea, and northward to and beyond the Town of Hokitika. The recent marine terraces are to be found all along the shore of the Tasman Sea parallel to the sea-beach.

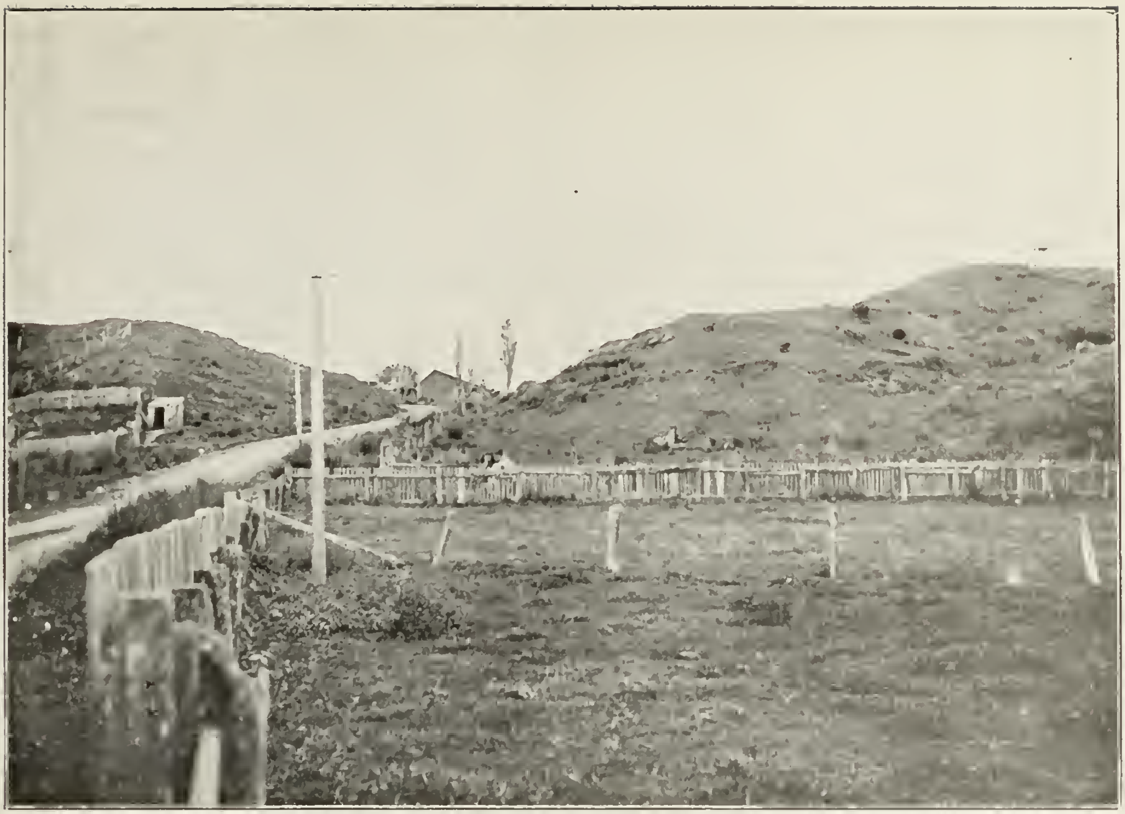
### *Leads on the Older Marine Gravels.*

The various terraces of marine gravels which enclose the old well-known richly alluvial ground of the Big Paddock, Hau Hau lead, and Bluespur all lie between the lower reaches of the Hokitika and Arahura Rivers, on the western flanks of the more elevated country of the Bluespur Range. These have been sufficiently well described by Mr. McKay in 1893. At the present time little can be gathered from an inspection of the many old workings of the locality. The situations of all of these leads are within a short distance of the Town of Hokitika.

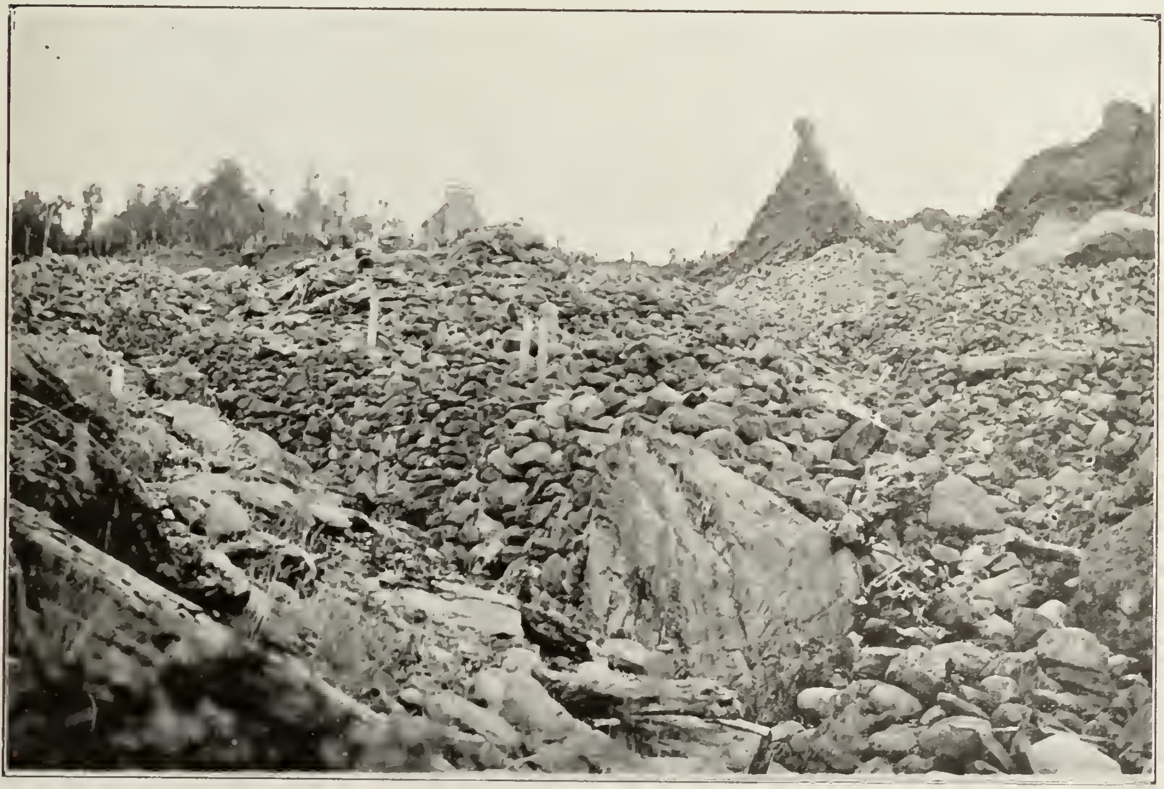
In the Bluespur locality in the flat to the south of the tavern, and at a point about 125 ft. above Bluespur Creek, a section was made of the marine gravels, which were then found to be disposed as follows above a basement of sandy Blue Bottom lying horizontally: 13 ft. of gravel and sand; 18 ft. 10 in. of hard, rusty gravelly sandstone, with only slightly consolidated rusty sands; 24 ft. 6 in. of faintly stratified cobbles and boulders, granite, grauwacke, &c., all more or less rounded.

There are old workings in glacio-marine gravels along the high terraces west of Arthurstown, towards the claim of Craig's Freehold, at present working.

The terraces of Craig's Freehold and of the area immediately to the south rise to a height of 70 ft. above the sand-dunes and beach deposits, and are situated about a mile southward of the mouth of the Hokitika River. As the claim is now being worked, it can be more easily studied at present than the abandoned claims. The terrace material consists of fairly fine marine gravels, resting on sandstone and clays of the Blue Bottom. The horizon which constitutes the greater portion of the payably auriferous material is composed of ferruginously cemented beach sand. The face of the main drive, which is in 1,500 ft. from the terrace-front, shows highly payable



The Terminal Moraine near Kanieri Township.



Sluiced Ground near Rimu.

ground. In order to disintegrate the cemented sands for the subsequent concentration treatment a light five-stamp battery is employed by the Craig's Freehold properties.

### *Leads of the Modern Marine Gravels.*

Recent littoral deposits form a fringe of low country extending along the whole length of the present coast-line. This belt is usually limited to a width of from 15 to 50 chains, skirting a terrace escarpment of the more elevated morainic deposits; but in the vicinity of the Hokitika and Totara Rivers the limiting terrace recedes from the coast-line, and the deposits are here separable with difficulty from those directly due to fluviatile agency. Lagoons, swamps, low sandhills, sandy grassed flats, and æolian deposits characterize this country in the rear of the actual shore-line. The littoral deposits are of importance, mainly because they include the auriferous black-sand leads, which have contributed so largely to the gold-output of the West Coast in the past.

Just below the present high-water mark black sand is often a conspicuous feature on the shelving beach, the action of the waves being to effect a concentration of the titaniferous magnetite, garnets, gold, and other materials of high specific gravity occurring within the ordinary grey sand. Marine action, however, is never constant at any particular point, and a storm may either cause this stratum of black sand to be buried under a protecting layer of grey sand, or not infrequently may result in the complete removal of a considerable thickness of such auriferous deposits. On the whole, however, in the past, deposition has been in excess of erosion, since a constant supply of material has been brought to the sea by the rivers, while the shore-line has probably been undergoing a very gradual elevation. In the manner above indicated a sandy deposit has been formed in which seams of auriferous black sand of greater or lesser extent frequently occur. This deposit may be said to extend from the existing coast-line to the base of the high terrace escarpment, and in the vicinity of the rivers to the point where the deposits of the littoral zone merge into those due to fluviatile action. The source of this gold associated with the black sand must be attributed both to the auriferous sands and gravels derived directly by the rivers from the older rocks of the mountainous country, and to fluviatile and marine erosion of the various pre-existing auriferous drifts of the coastal plain. A strong ocean current having a constant north-easterly direction prevails along the coast-line, and it is therefore possible that a portion of the gold of these beaches may have its source further to the southward. The gold of the black-sand deposits is very fine, and, as it is constantly associated with material of a high specific gravity, the recovery of a high percentage presents some difficulty. The various methods of recovery known as "beach-combing" have already been described, while in suitable localities dredging has been carried on with some success.

### FLUVIATILE GRAVELS.

Fluviatile gravels have a great development throughout the whole area under consideration, and in the main range in age from the period of maximum advance of the glaciers up to the present. Possibly, however, succeeding the elevation of the Humphrey's Gully beds, and prior to the maximum advance of the glaciers, *débris* carried down by the torrential rivers emanating from the ice-mass resulted in the formation of gravel-deposits, which are difficult to distinguish from the modern gravels of similar character. As will be referred to later a great proportion of these fluviatile beds consist of reassorted morainic material, and consequently there is every gradation between glacial, fluvio-glacial, and fluviatile deposits. As might be expected these fluviatile gravels have their greatest development within the valleys of the principal rivers. They are most marked west of the points where these debouch on to the coastal plain, but within the mountain track of the rivers such deposits often form a conspicuous feature occurring frequently at very high elevations.

Along the stretch of the Teremakau River, which is included within the Hokitika Sheet, only remnants of the higher-level terraces are met with, but extensive gravel beaches and grassed flood plains of more or less extent predominate. The Taipo River, however, in its lower reaches cuts through enormous deposits of fluviatile gravels, which often present high vertical faces. These deposits are, on the whole, the result of the torrential streams which marked the decline of the glacial period; the material has received only a rude concentration, and payably auriferous gravels are seldom present. The high terraces incised by the Seven-mile Creek at its junction with the Taipo formerly received some attention from miners, but the workings are now abandoned, and only the recent gravels of the wide delta-like flat of the Seven-mile Creek are from time to time worked for gold. The locality known as Fine Gold Terrace, on the south side of the lower gorge of the Taipo, has also yielded a little gold in former days.

In the Arahura River valley, within the limits of the coastal plain, the most conspicuous high-level fluviatile gravels are met with above the junction of the Kawhaka Stream. These flank on the southern side of the river the rising country of the Humphrey's Gully Range, while on the north side an abrupt escarpment often exceeding 200 ft. in height marks the incision of the river through these deposits. Below the junction of Caledonian Creek with this river these high terraces have been sluiced for gold, but apparently with limited success.

At Fox's, a locality about a mile and a half to the north of the Arahura River and drained in part by a small tributary stream of that river, a considerable amount of alluvial gold has been mined. The auriferous drifts which here overlie the Blue Bottom would appear to be due to a double concentration of morainic material, the first by the action of the Arahura River subsequent to the retreat of the glaciers, and the second by the several minor streams which have here incised the reassorted deposits.

At Bluespur the horizontally stratified sandy clays of the Blue Bottom form a hill with an elevation of 625 ft., or 475 ft. above the general surface level of Bluespur Valley, and are at the apex overlain by coarse morainic material amounting to some 25 ft., which itself includes lensoid layers of horizontally stratified sands. On the northern side of this hill a claim is being worked in vaguely stratified gravels and fine sands which abut against the Blue Bottom slope. The pebbles, consisting chiefly of grauwacke and sandstone, are less important than the sands. These beds have the appearance of being deposited in the sea from streams issuing from ice close at hand. They have a general resemblance to the Humphrey's Gully beds. Close to this claim on the western face of the hill a large face has been worked in beds of coarse cobbles overlain by finer gravels, and both above a basement of sandy Blue Bottom. At the head of McIntyre's Creek in this same locality another small claim is being worked in faintly reassorted morainic material, situated in a glacially gouged valley in sandy Blue Bottom containing layers of boulders.

The recent flood plains of greatest extent bordering the Arahura River are situated just below the junction of the Kawhaka River, above the junction of Caledonian Creek and between the head of the first gorge and the junction of Mount Brown Creek. The old glaciated valley of the Upper Arahura has been to a great extent refilled by the enormous amount of reassorted glacial *débris* carried into it by the torrential streams which have acted since the decline of the glacial period. Through this material the river has incised its channel, and vertical terrace faces or steep slopes rise from the gravel beaches of its present bed. The most extensive recent low-level flood plains are met with above the junction of Jack's Creek, and from the head of the Third gorge to the junction of the small creek which rises on the Styx Saddle. The fluviatile deposits of the Upper Arahura Valley, though slightly auriferous, have not been subjected to sufficient concentration to render them of any economic importance. Fine gold can, however, be panned at almost any point in the actual river-bed.

Within the area influenced by the Hokitika River and its various tributaries fluviatile deposits abound. The older of these deposits of the Hokitika River valley are of prime importance, in that they have so largely contributed, and still continue to contribute, to the gold-output of the West Coast. Skirting this river are the alluvial diggings of Kanieri, Woodstock, Rimu, Back Creek, and Seddon's Terrace. All the bonanzas of these gravels must be attributed to the reconcentration by fluviatile agencies of the gold formerly sparsely distributed throughout earlier fluviatile and morainic deposits. At Kanieri the auriferous drifts appear to be the result of reassortment by stream-action of the morainic material contributed by the piedmont glaciers of the last ice-advance, and values are found to fail off as the reassorted or fluvio-glacial drift gives place to unstratified boulder clays. Unassorted morainic material, the result of the maximum ice-advance, probably was formerly continuous from the Bluebottle Terrace across the present bed of the Hokitika River to the localities of Seddon's Terrace, Back Creek, &c. The cutting-through of this heavy deposit of slightly auriferous morainic *débris* by the Hokitika River and Kanieri Creek has resulted in the formation of extensive payably auriferous fluvio-glacial deposits, close to the margin of the Hokitika, which overlie the marine sands and clays of the Blue Bottom. At Back Creek Terrace prospecting-tunnels, advanced some 500 ft. from the terrace escarpment, have proved the existence of a considerable extent of auriferous drift, which is payable provided an efficient high-pressure water-supply is available. The Rimu Flat, which is the scene of extensive old workings, probably marks an older channel of the Hokitika River.

Along the valley of the Kanieri Creek fluviatile and fluvio-glacial terraces, overlying the Blue Bottom and flanking the more elevated deposits of morainic material, are a conspicuous feature. The greater part of Bluebottle Terrace has not been subjected to sufficient reconcentration to render the drifts payable, but "runs" of gold may yet be found on or near the Blue Bottom, which must underlie at no great depth the northern fluvio-glacial portion of this terrace. Prospecting-drives from the level of the flat south of Stripland Creek would appear advisable if this point has not already been systematically prospected. Kanieri Forks, which marks the junction of Kennedy's Creek and the Bluebottle with the Kanieri River, was formerly the scene of active mining operations. The old working-faces here show in their lower portions reassorted stratified material evidently derived from boulder clay, whereas the upper 10 ft. shows no stratification whatever, and may exhibit a moraine due to the last glacial advance.

The reconcentrations of morainic and partially reassorted morainic materials by the waters of Butcher Creek and Coal Creek yielded in the past a considerable amount of gold as the result of sluicing operations, so long as the operations were confined to the creek-beds and their immediate vicinities. Beyond the influence of the present creeks, however, the drifts, though gold-bearing, are not payable under existing conditions.

In connection with the occurrence of the gold in the drifts at present being worked on a small scale in the lower portion of Butcher's Creek, the following is of interest. It has constantly been observed by the miners that gold was more abundant in the wash immediately surrounding certain grauwacke boulders than in that surrounding boulders of granite, schist, quartz, or other rocks. Such could hardly be regarded as a coincidence, nor could the stone have yielded more than a negligible amount of the gold, so that the only conclusion possible is that the stone supplied the precipitant which acted on auriferous solutions percolating through the drifts. An analysis of the rock supports this conclusion, as it was found to contain 3·08 per cent. of ferrous carbonate, which would be soluble in waters carrying $CO_2$ or in weak acid solutions which might be expected to result from the decomposition of the pyrites frequently occurring in the rocks. In the manner indicated a precipitant would be supplied, and it is possible that solution of fine gold and reprecipitation according to the laws of mass-action are constantly going on.

The various fans of the high-grade creeks flowing into Kanieri Lake on its eastern side have resulted in the formation of a fringing, slightly inclined terrace, which is being brought under cultivation. Gold, however, is absent as the creek *débris* is wholly derived from the granitic rocks.

The Styx River, one of the principal branches of the Kokatahi, has throughout a great part of its course incised deeply into a great accumulation of fluviatile material, which filled its wide glaciated valley subsequent to the period of maximum glaciation. This material now forms vertical faces sometimes exceeding 300 ft. in height, but like that occurring in the upper valleys of the Arahura and Taipo, it was never subjected to the necessary reconcentration which is productive of payably auriferous drifts.

The more recent fluviatile deposits of the Hokitika River valley form the extensive area extending from Kanieri to the coast-line, and merge invisibly into those of the littoral zone. Following the river above Kanieri the recent low flood plain gradually widens out up to a point just below the junction of the Kokatahi with the main river, where it enters upon the relatively extensive river flat known as the Kokatahi Plain. In the Styx Valley, low flats, usually alternating on each side of the lower reaches of the river, occur at the base of the high-level terraces above described.

In the valley of the Upper Wilberforce recent and older terraces of fluvio-glacial material and enormous fans of *débris* delivered to the main river by the various lateral streams flank the wide gravel beaches. These are auriferous, though never payably so, owing to insufficient reconcentration.

# CHAPTER XII.

## *RESUMÉ* OF THE ECONOMIC POSSIBILITIES OF THE AREA CONSIDERED IN THIS BULLETIN.

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### GENERAL INTRODUCTION.

It will be seen on a perusal of the preceding chapters of this report that the economic possibilities of the area covered by the Hokitika Sheet are many and varied. Its forests, which extend over a great portion of the area, though especially important on the coastal plain, contain timber of great value, and represent much wealth to be developed in the future. In places its soil is rich and fertile, and there are still considerable stretches of unoccupied country to be denuded of their timber, and to be utilised for purposes of agriculture and pasturage. The numerous powerful rivers, with a rapid descent from the mountains to the sea-coast, exhibit immense stores of water-power for development. It is, however, with the mineral potentialities that we are especially interested. These include auriferous and platiniferous veins, gold-bearing gravels, greenstone, talc, coal, clays for brick-making, and stones for ornamental and building purposes.

### THE QUARTZ VEINS.

In the chapter on the veins of the Arahura and Kanieri series, the extensive distribution of quartz veins has been fully considered. In almost every part of the world where gold-bearing gravels of great value have been the result mainly or originally of the glacial erosion of an area of comparatively old or much-folded sedimentary rocks carrying auriferous veins, scientific and practical investigation has failed to reveal the huge mother lodes carrying the immense values which are always expected to occur as judged from the rich leads in the gravels. As a rule, a great many veins are found, most of which are not auriferous at all, while others carry good steady values, though never huge bonanzas. This seemingly paradoxical phenomenon is somewhat difficult of explanation. Gold, owing to the conditions which influence its deposition, apparently does not usually extend as payable quantities in quartz veins to great depths below the original surface—rarely below 3,000 ft.—and the richest portion of these veins is nearly always where a concentration of the precious metals has taken place near the surface. When subaerial erosion alone is active, a gradual downward migration of the belt of weathering near the surface takes place. It is supposed that much of the gold in the belt of weathering passes into solution owing to its solubility in ferric sulphate and other products of oxidation, and is precipitated from these solutions by unaltered sulphides and other precipitating agencies on gravitating to lower horizons in the veins. Thus an enrichment of quartz veins near the surface may result from the leaching of the vein-material which is continually being oxidized and removed from the upper portions. In the case of glacial erosion, the exceedingly rapid rate at which the surface-level is reduced does not admit of the existence of an extensive oxidized surface belt in which chemical actions giving enriched upper portions of the veins may take place. The disintegrated rock near the surface, due to subaerial erosion prior to a period of glaciation, and containing the enriched upper portions of the veins, is easily removed, and the vein-material contributes to the glacial *débris*, and thus to the placer deposits. In so far, then, as this glacial erosion does not extend beneath the level of original gold deposition, just so far are the remaining quartz veins auriferous, while as can be readily understood the rich upper portions of the veins have been removed, and the gold has been carried to supply the great wealth of the alluvium on the lowlands. This is probably exactly what took place in Westland, as in California, British Columbia, the Yukon, and elsewhere.

It may be here mentioned that it is possible that much of the gold occurring in the drift of the West Coast has come not only from auriferous quartz veins but from mineralised grauwackes and argillites, often practically pyritised quartzites, which were seen at many localities in the interior, as at the head of Cascade Creek, in Dexter Creek, and elsewhere. An analysis of samples from a great mass of this rock on Cascade Creek gave the following values: Gold, 19 gr. per ton; silver, 11 gr. per ton: worth in all some 3s. 2d. per ton.

In the area considered in this bulletin, by far the greater number of the veins are non-auriferous. These very probably are the mere lower remnants of former gold-bearing veins, of which the upper valuable portion has been eroded away, or, of course, they may represent veins which never were auriferous. Those which are still auriferous may be said to represent veins which have not been eroded below the level of original gold-deposition.

Only those veins occurring in two parts of this area may be said to present possibilities for commercial development—namely, those in the immediate vicinity of the Pounamu intrusive formation, and those lying within a belt of country approximately five miles wide, situated to the eastward of an arbitrary line, "extending from the point where the eastern boundary of the Turiwhate Sheet crosses the Teremakau River, in a general direction of south 35° west, through the upper part of the third gorge of the Arahura to the western boundary of the Browning's Pass district some two miles and a half north of its south-west corner." Only within these two belts is prospecting for auriferous or platiniferous veins likely to meet with satisfactory results, as proven by our investigations.

The discovery of platinum-bearing quartz veins in the Taipo Gorge and in Harley's Creek—both close to the Pounamu belt of magnesian eruptives—is of great scientific signification and of some economic importance. Nearly all over the world platinum, when found in its original locus, is associated with highly magnesic eruptive rocks. At Nizhni Tagilsk, in the Ural Mountains of Russia, it occurs with serpentine supposedly derived from peridotite. In Northern Lapland it is supposed to be derived from an altered peridotite, and in Southern British Columbia it has also been found in connection with the same rocks. In these localities, however, so far as known, it occurs actually in the magnesian eruptives, while where found in the Taipo Gorge and in Harley's Creek it is in quartz veins, which are probably the result of the intrusion of the Pounamu magnesian irruptives, though actually in rocks of the Arahura series.

In the three instances where the platinum has been discovered silver is also present, and the fairly definite ratio of seven proportions of silver to one of platinum seems to suggest some mineralogical combination between the two metals. In only one of the three platiniferous veins noted—namely, one from Harley's Creek—may the platinum be said to exist in even approximately payable quantities, and in this case the vein is of very small dimensions. However, in the light of the small supply of platinum in the world and its distinctly increasing value, it would seem that the platinum veins discovered are economic possibilities, in that they may indicate other veins to be discovered in which the values may be higher. Prospecting on the three narrow veins already discovered would be a feasible undertaking, though from surface indications there is no evidence that they will increase in value or become wider in depth. Investigations for platiniferous veins may be conducted to possible advantage from the headwaters of Harley's Creek to the south-westward as far as Griffin Creek, and always within a short distance—about a quarter of a mile—from the edge of the Pounamu rocks. South-westward from Griffin Creek no evidences of platinum were discovered, though samples of quartz from several veins were analysed.

It will be seen that the belt in which gold-bearing veins occur is much more extensive than that in which platinum silver-bearing veins may be reasonably looked for. The auriferous belt, within the limits of the area covered by the present report, is, however, practically limited to two localities—the broad valley of the Taipo above the mouth of Seven-mile Creek, and the area around Browning's Pass at the headwaters of the Wilberforce and Arahura Rivers. For experienced prospectors both localities are easily reached. Compared with that of the other Westland rivers the Taipo is very accessible, and it forms an excellent base to work the hills to the east and west, while a good track leads into the heart of the Browning's Pass country up the valley of the Arahura from the West Coast Despite the work of previous able prospectors and the detailed geological investigations conducted by our survey, neither the Browning's Pass area nor the Taipo Valley has been thoroughly prospected, and there is every possibility that within the limitations above given further auriferous veins may be discovered. A careful search near the head of the Taipo, in the neighbourhood of Gold Creek, and in the headwaters of Hura and McQuilkin's Creek would seem to be especially likely to lead to good results.

On the Taipo only two veins of any economic value have been located in the area at present considered—one at Taipo Corner and the other at Gold Creek. Both carry low values throughout their width, and the latter contains a highly auriferous paystreak. Both these veins may be considered to be distinctly fair prospects. The uniform values carried by the Taipo Corner reef wherever specimens are taken may be considered a hopeful sign, and possibly exploration-work along the line of strike might reveal the presence of a paystreak.

One of the most striking features of the Westland reefs (those near Browning's Pass) is the low or actually negative values carried by the great proportion of the quartz and the occasional very high values of some of the quartz. Fiddes's and Pfahlert's reefs may in general be considered very favourable prospects, and quite the most so of the Browning's Pass area. From both of these veins, however, general samples taken along their line of strike, and picked free from visible gold, were found to carry relatively low values, while very high values were obtained when the quartz with the rusty slaty selvages carrying free gold was analysed. That both Pfahlert's and Fiddes's reefs are continuous for some distance in both horizontal and vertical extension there can be no doubt. In the case of Wilson's Reward, which, owing to the large amount of vein-material, seems a fair prospecting proposition, the values of a general analysis of samples picked free from visible gold are extremely low, but here again fairly high values are indicated when analyses are made of quartz carrying small specks of free gold, a feature which is not uncommon along certain of the rusty slaty selvages. It is evident that neither the analysis of quartz absolutely devoid of visible gold nor of quartz carrying the precious metal in slaty selvages is really representative of any of these lodes—Fiddes's reef, Pfahlert's reef, or Wilson's Reward. In fact, it is only by crushing large samples of quartz from the three reefs that the actual value of each lode can be obtained. What is wanted seems to be the erection of a small battery in the basin of the Wilberforce, in such a position that quartz can be fairly easily transported to it from the three reefs. By this means a definite idea of the true value of the reefs may be ascertained at a comparatively small cost. This battery could be worked easily from the good water-power to be obtained from Hamer Falls.

### THE AURIFEROUS GRAVELS.

In the past immense amounts of gold have been obtained from the gold-bearing gravels of the Hokitika area, though very little is now being recovered. The rich leads are the result of concentration. The first transportation of gravel from the mountains was by streams, and following this the glaciers carried much material from the interior seawards. On retreat of these glaciers immense masses of drift were deposited all over the lowlands, and even high up on to the lower hills. Since glacial times the rivers have continued the movement of gravel from the interior to the sea.

The material brought by the rivers prior to the advance of the glaciers probably all bore fine gold, though never in great quantity, and only when reconcentrated by the waves on the sea-shore did it become rich enough to work. As samples of these gravels, the beds now worked at Humphrey's Gully may be mentioned.

Probably all the glacial *débris* deposited by the great ice sheet in its maximum extension is auriferous, though rarely rich enough to be worked economically with the means at our present disposal. Concentration of this ice-brought material (1) by secondary or minor ice-advance, (2) by stream-action, or (3) by the action of the waves on the sea-shore gave the payable gravels which have been of such immense value in the past, and which will probably yet be of great importance on the West Coast. The richest leads were obtained probably where more than one of the secondary agents worked on the original material. Thus it seems likely that the very rich leads at Kanieri originated from the concentration by stream-action of material transported by the ice in its period of maximum extension, and subsequently reassorted by a minor glacier in the Hokitika Valley, probably in the time of its retreat by the englacial streams. The rich leads along the present sea-shore line and those along old shore-lines—as at the Hau Hau, Mahinapua Beach, &c.—were most likely, in the main, the result of concentration by sea-waves, though possibly in part by streams flowing from the ice-front during the glacial extension.

The bonanzas at Greek's Gully and Fox's were in gravels, which represented a reconcentration by small-stream action of morainic material, reassorted by the action of the Arahura River subsequent to the glacial period.

It will be seen from these few remarks that the gravels are payable chiefly where a sort of natural "panning" has occurred, and very rich only where one or more processes of concentration have acted on the original material. This concentration is proceeding to-day along the sea-shore, as every miner on the beach realises, and valuable, though limited, leads are to be found occasionally after a heavy gale. Along the rivers in the interior concentration is also progressing, though the enrichment is so slow as to be scarcely observable. On the Seven-mile Creek, however, after every flood small patches of payable gravels are found near its mouth.

A very great deal of the drift of the Hokitika area has not been thoroughly prospected, though the leads most apparent on the surface have for the most part already been worked. There is, however, undoubtedly much of the precious metal yet hidden away in the gravels which is not so evident superficially. From surface examinations it is quite impossible to say where these leads are, and the only way to ascertain their existence is by systematic prospecting, shaft-sinking, test pitting, &c., in favourable localities where reassortment by river or wave action of gravels which were originally auriferous has been known to have taken place. As every digger on the West Coast knows, the leads occur in connection with the coarser and heavier gravels, and frequently associated with black sand. Of favourable localities the most prominent are perhaps the following: The various terraces of the Arahura Flat, below Humphrey's Gully to the edge of the Hokitika Sheet; the prominent terraces around Rimu and Woodstock; the old channels of the Hokitika River, near the Bluebottle Terrace; the old channels of Kanieri Creek, north and east of Cardiff Terrace, near the Township of Kanieri; the old sea-beaches between Lake Mahinapua and the sea, and northward from Lake Mahinapua, east of Mahinapua Creek towards the mouth of the Hokitika River.

There are great possibilities in the widely extended beds of Humphrey's Gully, beneath the morainic material, and apparently much more of these could be worked to advantage with a still greater supply of water than is at present available for sluicing. Near Rimu and Back Creek and westward towards the sea-shore there are immense stretches of gravels derived from glacial *débris*, and reassorted in great part by fluviatile and partly by marine action; these deposits, with a good supply of high-pressure water, could be sluiced to advantage, since nearly all of this material is decidedly auriferous, though not in many places payably so with the amount of water at present at hand. It is, however, unlikely that there are very many bonanza leads in this material at Rimu and Woodstock, nor in the Humphrey's Gully beds, as the gravels have not in general undergone sufficient reassortment to give the necessary gold-concentration. The extensive gravel-beds near Kanieri Forks would seem to offer good possibilities for sluicing operations, though they would require much careful prospecting before this was undertaken. The sinking of shafts and test pits in old channels of the Kanieri Creek, between Kanieri Township and the mouth of Stripland Creek, and of the Hokitika River, near Kanieri Township, would not improbably meet with much difficulty, owing to the influx of great quantities of water, otherwise they would appear to be favourable localities for further prospecting.

The possibility of the existence of deep leads beneath the thick beds of the Blue Bottom has often been suggested by the diggers of the West Coast, and the idea seems to be a sane one, since there was undoubtedly erosion of the folded sedimentary rocks which bear the auriferous veins prior to and during the deposition of the Blue Bottom, and subsequent to the orogenic movement which folded the Koiterangi series. Some years ago a drill-hole was sunk near Rimu about 400 ft. in order to test this deep-lead hypothesis, but it was abandoned while still in the Brighton Bottom (or Blue Bottom). The most favourable localities for the sinking of drill-holes to prospect for deep leads and to ascertain their existence or non-existence would be near the edge of the old land, especially where the old Miocene rivers flowed into the sea of that period. Such localities are, however, very difficult to identify at the present day. The Arahura very probably still follows the same channel as in Miocene times.

Detrital gold is said to have been found in the ferruginous conglomerates of the Koiterangi series at the base of the mountain of the same name, though we were unable to verify this statement by our own investigations.

### THE POUNAMU BELT.

Among the most interesting features of the economic geology of the area covered by the Hokitika Sheet are the intrusives of the Pounamu formation. These remarkable magnesian sills in their various exposures throughout Westland are said to contain almost every known metal, except tin, and even within the Hokitika Sheet the mineral range is enormous. The discovery of the mineral nephrite, more popularly known as "greenstone," or the pounamu and tangiwai of the Maoris, is of scientific and popular interest and of economic value. So far as known the mineral has not heretofore been found in its original locus in this area. As already mentioned in the detailed chapter on this subject, the mineral occurs in segregations in a talcose or serpentinous matrix. It was found in large segregations in one place only—namely, at the head of Griffin Creek, high up on the Griffin Range. Though sometimes of fine, dark translucent character it is more often impure, but undoubtedly many tons of fair quality could be obtained from this locality. Without intending to claim prescience, there seems no reason why other localities containing this valuable mineral should not be found in the still little-explored part of the belt running from the Razorback Ridge towards McArthur Crags. Rubies and copper-ores—evidences of both of which have been seen—may also possibly be discovered in this part of the belt.

The deposits of talc and steatite of fair quality and in some quantity are economic possibilities. The dark-green and greenish-grey serpentine rocks which occur in quantity on Griffin Range and elsewhere would be of great value for ornamental purposes. When polished they are especially handsome, rivalling those of the Lizard district, in Cornwall, England. There is a possibility of platinum, gold, and silver being found in the rocks of the Pounamu formation. A specimen of a small fragment of an erratic rock, very rich in magnetite, from the Arahura was analysed by Mr. Sidney Fry, Director of the Westport School of Mines, who announces that this gave assays of gold from 5 dwt. up to 1 oz. 6 dwt. per ton.*

### COAL, BUILDING-STONE, ETC.

The coal of the Hokitika area does not seem to be of very great value. That of the Gentle Annie portion of the country is certainly of value for use in the immediate locality should it be required there. On Koiterangi Hill the coal is explored at only a few places, and where appearing on the surface is of low grade. Between these several outcrops, however, there is an area of fair size beneath which coal probably lies. It is most unlikely that coal should be found over any considerable area beneath the low-lying country of the Kokatahi Plain between Koiterangi and Gentle Annie, because there all the once extensive strata of the Koiterangi or coal-bearing series have been removed by preglacial and glacial erosion.

The widely distributed granites of various shades of pink and grey, and often of fine texture, are of value for masonry and general building purposes, while the finer porphyritic varieties could well be put to more ornamental uses. There are many patches of good granite, both non-porphyritic and porphyritic, which might be utilised. The clays of the Blue Bottom seem excellently suitable for brick-making, and might in places be used for the manufacture of the cheaper kinds of pottery, though they apparently generally contain too much iron.

The hot springs of the Taipo River might be put to commercial use, since, owing to the large amount of hydrogen-sulphide contained, the water is of some value for medicinal purposes.

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* C.-3, page 27, New Zealand Parliamentary Report, 1905.

# APPENDIX.

THE following is a list of common alpine plants found within a radius of ten miles of Browning's Pass, collected by Mr. H. M. Macpherson, and identified through the kindness of A. H. Cockayne, Esq., B.Sc.:—

Aciphylla monroi.
Aciphylla sp.
Anthericum hookeri.
Celmisia armstrongii.
,, coriacea.
,, incana.
,, petiolata.
,, sessiliflora.
Claytonia australasica.
Coprosma cuneata.
,, serrulata.
Coriaria sp.
Craspedia uniflora.
Donatia novæ-zealandiæ.
Drapetes lyallii.
Drosera arcturi.
Epilobium sp.
Euphrasia sp.
Forstera sedifolia.
Gaultheria antipoda.
Gentiana sp.
Geranium microphyllum.
Geum parviflorum.
,, uniflorum.
Haastia sinclairi.
Helichrysum bellidioides.
,, grandiceps.
Ligusticum sp.
Mimulus radicans.
Myosotis sp.
Ourisia cæspitosa.
Ourisia macrocarpa.
,, macrophylla.
,, sessilifolia.
Pratia macrodon.
Ranunculus godleyanus.
,, hirtus.
,, lyallii.
Raoulia grandiflora.
Senecio bellidioides.
,, scorzonerioides.
Veronica haastii.
,, linifolia.
,, macrantha.
Viola lyallii.
Wahlenbergia saxicola.

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## BULLETIN No. 1 (NEW SERIES) NEW ZEALAND GEOLOGICAL SURVEY.

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